The United Republic of Tanzania

The Project for Domestic Natural Gas Production and Supply System in Tanzania

Report

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The Institute of Energy Economics, Japan (IEEJ)

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Abbreviations

Acronym	Definition
AfDB	African Development Bank
AFVs	Alternative Fuel Vehicles
ASEAN	Association of South East Asian Nations
BAU	Business as Usual
Bcm	Billion cubic meter
Bcf	Billion cubic feet
BOG	Boil-off Gas
Btu	British thermal unit
CAPEX	Capital Expenditure
CBD	Central Business District
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Dioxide Capture and Storage
CEF	Connecting Europe Facility
CHP	Combined Heat and Power
CIF	Cost, Insurance and Freight
CNG	Compressed Natural Gas
COP	Conference of Parties
CP	Contract Price (of Saudi Arabian LPG)
CSR	Corporate Social Responsibility
DAFI	Directive for Alternative Fuels Infrastructure
DES	District Energy System
DFI	Development Finance Institution
DME	Di-Methyl Ether
DNGPP	Domestic Natural Gas Promotion Plan
DOE-PVO	division of Environment, Vice-President's Office
EAC	East African Community
EASS	Energy Access Situation Survey
ECAs	Export Credit Agencies
EDMC	Energy Data and Modelling Center, IEEJ
EHS, SHE	Environment, Health and Safety; Safety, Health and Environment
EIA	Environment Impact Assessment
EMA 2004	The Environmental Management Act 2004
EMP	Environment Management Plan
EPs	Equator Principles

ESCO	Energy Service Company
ESFI	European Fund for Strategic Investments
ESG	Environmental, Social and Governance
ESMP	Environmental and Social Management Plan
EWURA	Energy and Water Utilities Regulatory Authority
FEED	Front End Engineering and Design
FID	Final Investment Decision
FLNG	Floating LNG
FREL	Forest Reference Emission Level
FS	Feasibility Study
FSRU	Floating Storage and Regasification Unit
FSU	Floating Storage Unit
GASCO	Gasco(T), a subsidiary of TPDC in charge of gas operation
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHP	Gas Heat Pump
GIIP	Gas Initially In Place
GTL	Gas to Liquids
GWh	Giga Watt Hours
HDTs	Heavy Duty Trucks
HDV	Heavy Duty Vehicle
HGA	Host Government Agreement
HPDI	High Pressure Direct Injection
IBRD	International Bank for Reconstruction and Development
ICIS	Independent Commodity Intelligence Service
IDA	International Development Association
IEA	International Energy Agency
IEEJ	The Institute of Energy Economics, Japan
IFC	International Finance Corporation
IHS CERA	IHS Cambridge Energy Research Associates, Inc.
IMF	International Monetary Fund
IMO	International Maritime Organization
INDCs	Intended Nationally Determined Contributions
IOC	International Major Oil Company
IRR	Internal Rate of Return
ISO	International Organization for Standardization

IT	Information Technology
JAPEX	Japan Petroleum Exploration CO., LTD.
JCC	Japan Crude Cocktail
JICA	Japan International Cooperation Agency
JKM	Japan/Korea Marker (of LNG price)
JLC	Japan LNG Cocktail
ktoe	Thousand tons oil equivalent
LBM	Liquefied Bio Methane
L-CNG	Liquefied-Compressed Natural Gas (Service Station)
LGV	Light Goods Vehicle
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LPV	Light Passenger Vehicle
MLHHSD	Ministry of Land and Human Settlement and Housing Development
MM	Million
MMBtu	Million BTU
MMcfd	Million cubic feet per day
MN	Methane Number
MOE	Ministry of Energy
MoWTC	Ministry of Works, Transport and Communications
MTG	Methanol to Gasoline
Mtoe	Million tons oil equivalent
MTPA	Million Tons Per Annum
MW	Mega Watt
MWh	Mega Watt hours
NBP	National Balancing Point
NBS	National Bureau of Statistics
NEEC	National Economic Empowerment Council
NEMC	National Environmental Management Council
NG	Natural Gas
NGC	New Government City
NGUMP	Natural Gas Utilisation Master Plan
NGV	Natural Gas Vehicle
NGV	Natural Gas Vehicle
NOx	Nitrogen Oxide
NPF	National Policy Frameworks

NPV	Net Present Value
O&M	Operation and Maintenance
OECD	Organisation for Economic Cooperation and Development
OPEC	Organization of the Petroleum Exporting Countries
OPEX	Operating Expenditure
PHD	Propane Dehydrogenation
PM	Particulate Matter
PMO-RALG	Regional Administration and Local Government, Prime Minister's Office
PNG	Piped Natural Gas, Pipeline Natural Gas
PS	Performance Standards
PSA	Purchase and Sale Agreement
PSMP	Power System Master Plan (of Tanzania)
PV	Photovoltaics
RAHCO	Reli Assets Holding Company
RAP	Resettlement Action Plan
REDS	Regional Energy Demand Survey
REME	Regional Environmental Management Expert
RITES	Rail India Technical and Economic Service Limited
RPF	Resettlement Policy Framework
SADC	Southern Africa Development Community
SDGs	Sustainable Development Goals
SEA	Strategic Environment Assessment
SEZ	Special Economic Zone
SGR	Standard Gage Railway
SMDS	Shell Middle Distillate Synthesis
SMR	Single Mixed Refrigerant
SOx	Sulphur Oxide
SS	Service Station
SUMATRA	Surface and Marine Transport Regulatory Authority
TAC	Technical Advisory Committee
TANESCO	Tanzania Electric Supply Company, Limited
TANROADS	Tanzania National Roads Agency
TARURA	Tanzania Rural and Urban Roads Agency
TAZARA	Tanzania & Zambia Railway Authority
TBS	Tanzanian Bureau of Standards
Tcf	Trillion cubic Feet

TDV	The Tanzania Development Vision
TEN-T	Trans-European Network for Transport
TIRP	Tanzania Intermodal and Rail Development Project
TPA	Tanzania Ports Authority
TPDC	Tanzania Petroleum Development Corporation
TRC	Tanzania Railways Corporation
TRL	Tanzania Railways Limited
TSIP	Transport Sector Investment Program
TSSP	Transport Sector Support Project
TzS	Tanzanian Shilling
UNFCCC	United Nations Framework Convention on Climate Change
UNPRI	United Nations Principles for Responsible Investment
UTCOP	Uganda-Tanzania Crude Oil Pipeline
VP	Virtual Pipeline
VPO	Vice President's Office
WMA	Wildlife Management Area
WTI	West Texas Intermediate

Part-1 Natural Gas Supply System for Domestic Market of Tanzania

A significant amount of natural gas is found in Tanzania. This study is aimed to develop a practicable plan to construct a gas supply system in the country so that Tanzanian citizens will be able to utilise these indigenous resources for their economic activities and daily life.

Since Tanzania is not densely populated, it is questionable if the traditional method of gas transport by pipeline would be viable. However, various technologies are developed recently to accommodate distributed smaller demands, which is called V*irtual Pipeline* as an integrated system. As analysed in this study, the Study Team recommends considering a mini-LNG based virtual pipeline system for introduction of natural gas into the domestic market. At the same time, the team recommends introduction of LPG in the areas that are not an immediate target of the natural gas introduction.

This study is composed of two phases. In Part-1, analysing various data and information after conducting the Regional Energy Demand Survey, a mini-LNG based system is selected as the preferable method of gas transport to the market. In Part-2, based on this finding, a draft Implementation Plan is developed to start introduction of natural gas.

Natural gas is penetrating rather slowly in Tanzania. There would be some vague anxieties that natural gas resources would be used up soon if big projects were implemented aggressively, or use of natural gas would be against the global movements toward a low-carbon society. However, the right and practicable pathway is to establish country's modern energy infrastructure first with clean natural gas, and after that decarbonise it as much as possible. The Study Team hopes that, despite many challenging issues, proactive policies will be placed to materialise use of natural gas in the domestic energy market.

Chapter 1 Outline of the Study

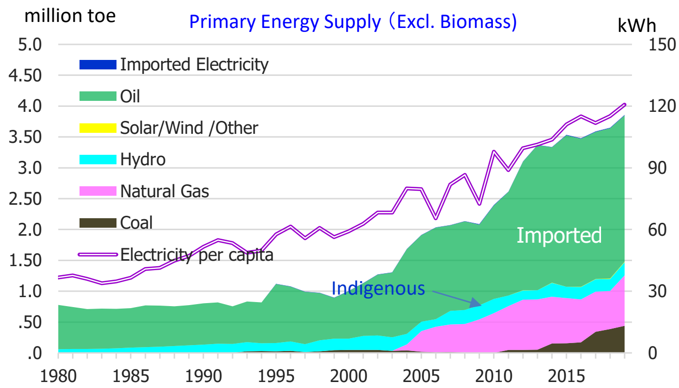
1.1 Background of the Study

The per capita energy consumption in Tanzania was 382kg in 2019, which equated to about one-fifth of the world average of 1,890kg. However, as 84% of that consumption was made up of conventional biomass such as firewood or charcoal[1], introduction and diffusion of modern types of energy such as electricity and gas are needed to promote modernisation of economy and improve people's quality of living in the nation.

In Tanzania, use of natural gas for power generation and industry started in 2004, after the World Bank decided in 2001 to support development of the Songo Songo gas field discovered back in the 1970s. However, consumption of natural gas in 2019 remained at a modest level of

[1] IEA World Energy Balances 2021. As explained in Appendix D, the Study Team think that consumption of traditional biomass is much smaller.

31 billion cubic feet (Bcf) or 818,000 tonnes of oil equivalent (TOE), due to constraints in resource availability and delays in infrastructure development. Other energy production included those of hydropower at 2,234 GWh (213,000 TOE) and coal at 712,000 tonnes (439,000 TOE). Consumption of petroleum products accounts for the largest share among the variety of commercial energies, and is growing rapidly since 2010 along with accelerating motorisation, while their supply entirely relies upon imports. Additionally, imported supply of LPG as home fuel is beginning to increase in recent years.



	2019	
	ktoe	
Coal	439	
Oil	2,371	
Natural Gas	818	Per Capita
Hydro	213	
NRE	8	
Imported Elec.	10	kg/year
Sub-Total	3,859	67
Biomass	18,296	315
Total	22,155	382
	World	1,890

Source: IEA, "World Energy Balances 2021"

Figure 1.1-1 Primary Energy Consumption in Tanzania

Construction of a long distance pipeline connecting the Mnazi Bay gas field located in Mtwara Region in the south to Dar es Salaam started in 2012. Upon its completion in 2015, a newly constructed Kinyerezi I Thermal Power Plant (150 MW) was commissioned. Following this, the Kinyerezi II Power Plant (240 MW) started operation in 2017. Construction plan of a world class fertiliser plant (1.3 MTPA) utilising the shallow water gas fields is reportedly under negotiation. Elsewhere, reported events such as discovery of a new gas field in the Ruvu Basin Block located 17km west of Dar es Salaam indicate that natural gas utilisation in Tanzania is gaining momentum.

All of the above-mentioned gas fields, although they are supposed to provide the main natural gas supplies for the near future, are small in reserve size at around 1 to 2 trillion cubic feet (Tcf). In recent years, however, large gas fields were discovered in deepwater blocks. This has expanded the natural gas reserves as Contingent Resources to as much as 57.54Tcf at the end of 2018, according to the Ministry of Energy (MOE). In support of the Government of Tanzania seeking to actively develop these newfound gas fields, Japan International Cooperation Agency (JICA) conducted in 2015 a study that produced a report entitled "The Project for Review of the Natural Gas Utilisation Master Plan in Tanzania". Building upon the JICA report on the above project, the government of Tanzania released in October 2016 the final draft of the Natural Gas Utilisation Master Plan (NGUMP).

The above announcement indicated that the government of Tanzania would in the future strive for (i) developing the deepwater gas fields focusing on LNG businesses, (ii) promoting the frontrunner projects such as fertiliser, methanol, etc. to make use of gas resources in the shallow-water fields, and also for (iii) responding to the strong public demand for the improvement of people's living and economic development through the use of indigenous natural gas. As Tanzania imports its entire petroleum supply from abroad, it will find the benefits of using natural gas in many areas as a modern fuel to replace petroleum products. Further, under the current situation where the large-scale development of coal resources has yet to begin in earnest, natural gas power generation with short lead time and relatively low initial investment will provide a promising option for expeditious development of power supply.

Reflecting the above circumstances, the NGUMP in the above announcement proposed to promote use of natural gas in the Lindi industrial development zone and Dar es Salaam district as a starting point and also to build a natural gas distribution system covering the whole country in the future. In Tanzania a gas transmission pipeline passing through the southern coastal area is completed, and construction of LNG plants and chemical industries is scheduled in the Lindi industrial district nearby the gas field. Additionally, gas utilisation for power generation, industry and other activities will be promoted in the Dar es Salaam district and along the pipeline system.

Despite the above status, discussions and studies on the nationwide use of natural gas is yet to progress. For example, the Dodoma Capital City Master Plan (2019-2039) recognises, with regard to cooking fuel, that “more than 82% of residents of Dodoma city depend on firewood and charcoal” and that “this high dependency on these natural resources is increasing deforestation in Dodoma city.” It also stipulates that “resident of Dodoma faces… high cost of energy.” However, no plan is discussed in the Master Plan to improve the situation[2]. To assure the sustainable development and modernization of Dodoma as the national capital, and also for other regions, it is necessary to consider introduction of clean and efficient modern fuel. To this end, city gas by way of virtual pipeline system will be the most preferred option.

To promote nationwide natural gas use in Tanzania that has vast land with low population density, a comprehensive study is necessary to prepare an overall plan addressing parameters such as future energy demand outlook in all regions, method of natural gas transportation and distribution commensurate with the demand scale of each region, geographical and social conditions and costs involved in configuring the integrated system, along with the progress in power development and other relevant factors.

Under the circumstance, this Study was proposed to investigate into these issues and formulate a Domestic Natural Gas Promotion Plan (DNGPP) to follow up the decision under the Natural Gas Utilisation Master Plan (NGUMP).

It should be noted here that both the LNG development based on the deepwater gas fields as

[2] Section 6.2.2 Energy for Cooking, Dodoma Capital City Master Plan (2019-2039)

well as the front runner projects such as fertiliser production using the shallow water gas fields are still in the conceptual stage, calling for support in many areas such as technology, financing, legal system, business management, etc. toward realisation of the goal in the future. Additionally, there is a strong desire to realise a society in which the Tanzanian public can widely use indigenous natural gas. Meanwhile, human resources to carry forward these giant projects are utterly in short as a reality, making human resource development a significant additional challenge.

1.2 Objectives of the Study

The objective of this Study is to assist the government of Tanzania in formulating a Domestic Natural Gas Promotion Plan (DNGPP) for promoting the nationwide utilisation of natural gas, with an aim of helping the government achieve effective and thorough utilisation of natural gas suitable for Tanzania's socio-economic as well as energy supply and demand situations and also taking into consideration the progress in various projects related to development of gas fields located in on-shore, shallow water, and deepwater tracts and of natural gas as well as gas power generation industries. The Study also intends to provide support for developing an Implementation Plan of the DNGPP, as well as to help the government acquire a capability to formulate and revise these plans by itself.

1.3 Study Organisation

This Study is carried out by the organisation illustrated in Figure 1.3. The Tanzanian organisation for this Study as the counterpart to the JICA Study Team is the Ministry of Energy (MOE), where Tanzania Petroleum Development Corporation (TPDC) acts as the main support agency in Tanzania.

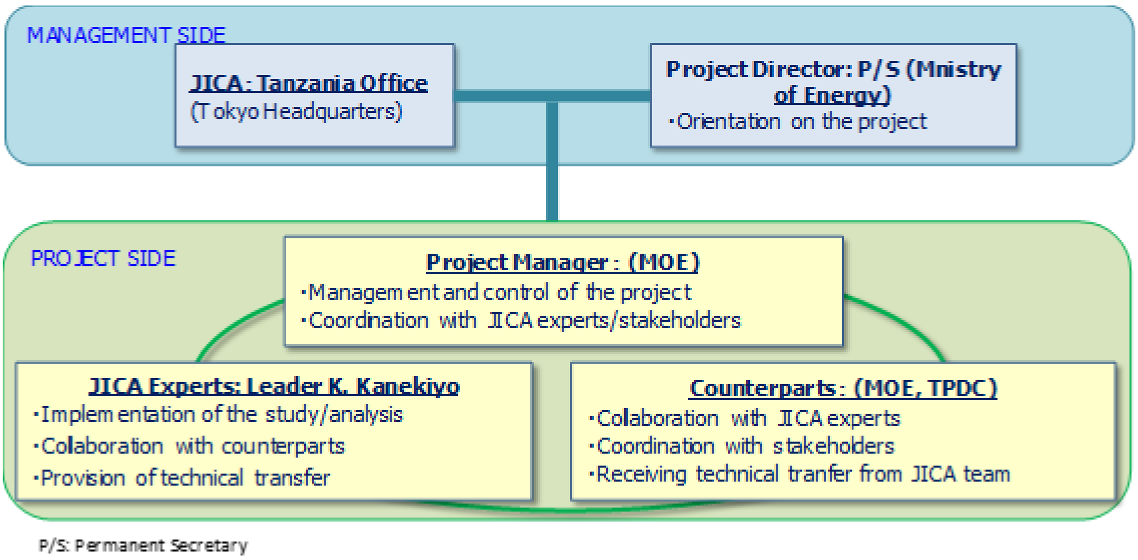


Figure 1.3-1 Study Organisation and Functions

1.4 Scope of the Study

In the final draft of the Natural Gas Utilisation Master Plan (NGUMP), it is proposed to construct a nationwide gas pipeline system in three phases and to start construction from the priority areas. In the Phase-I, it plans to construct pipelines for three routes:

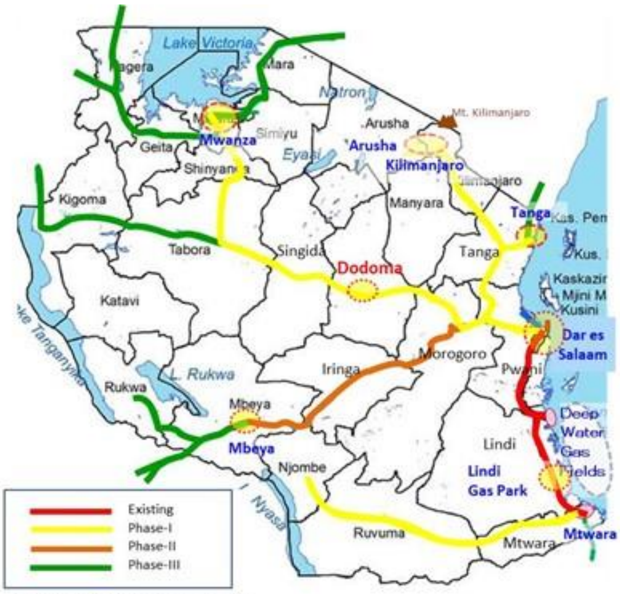
a. From Dar es Salaam via Dodoma through to Mwanza
b. Dar es Salaam via Tanga through to Arusha
c. Mtwara to Njombe

Pipeline is an efficient method to transport gaseous fuel. However, it is capital intensive and viable only for a demand above certain size. If energy demand is small and scattered with low concentration of population and industry, LPG will be preferred as a clean fuel which is easy to handle in a small quantity and less capital intensive though it needs to be imported from abroad.

In this context, the Study Team adopted an approach to consider a model gas supply project for a selected region. To consider realistic coverage, the Phase-I plan in the NGUMP is divided into three groups, A, B and C, based on the distance from Dar es Salaam (which will be the starting point of the pipeline), the industrial distribution and population density, and the Group-A cities are set as the target of this Study.

Group-A: Morogoro, Dodoma, Tanga, Moshi, Arusha
Group-B: Tabora, Mwanza
Group-C: Areas along the route from Mtwara to Njombe

As the potential gas demand in the object region is thought to be small and scattered, virtual pipeline systems using LNG and CNG are considered for natural gas transport and delivery in addition to a pipeline. If natural gas transport by such system is viable, it may be developed one after another. Since this process takes time, LPG may be adopted simultaneously elsewhere in the country.



出所: MEM, "NGUMP - First Draft"

Figure 1.4-1 Natural Gas Pipeline Development Plan

Given the above-described setting, the Study is implemented in two stages.

In Part-1, the following studies are conducted to identify the demand size for the model project and the preferable gas transport method:

a. Regional energy demand survey
b. Formulation of regional gas demand outlook
c. Setting of gas demand scenarios for model projects.
d. Development of model projects for gas transport options
e. Examination of comparative economics.

As a result, mini-LNG based virtual pipeline system is selected as the most suitable and practicable option for small scale gas transport to be considered in this Study.

Based on the outcome, a model Implementation Plan is developed in Part-2 as below:

a. Configuration of a mini-LNG plant
b. Transport and delivery of LNG
c. Configuration of a satellite LNG terminal
d. Development plan of city gas systems in Dodoma
e. Natural gas stations for NGVs
f. Feature of the business
g. Environmental and social considerations
h. Economics of the model project

Outcome of the study was reported at the symposium held in Dar es Salaam in January 2020. At the meeting after the symposium, Ministry of Energy requested deepening of the study as it contained considerable uncertainties. The Study Team conducted additional study, accordingly. Among others, more precise information on energy users in the target areas was deemed utmost important. Unfortunately, however, Study Team could not visit Tanzania since then due to outbreak of the COVID-19 pandemic. Under the circumstance, MoE conducted market research on the target areas in June-July 2021. The outcome is incorporated in this report.

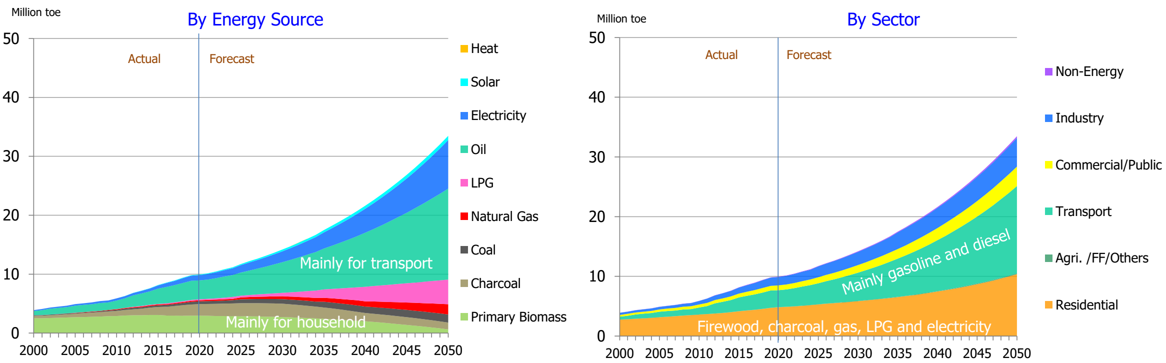
Main points of the study are summarised in Executive Summary below. In view of the individual energy market size, Study Team proposes construction of *a Virtual Pipeline system based on mini-LNG*. However, to make a step forward, many decisions must be made on energy policy including coordination among various stakeholders. These issues should be considered and solved in the next step.

In this study, human resource development programme was also implemented with its main objective to expand the pool of human resources possessing basic knowledge of the natural gas business in general. To that end, IEEJ has worked as a hub and sought support from a broad range of LNG importers and engineering enterprises in Japan to organise extensive training programmes which also included observation visits to the Brunei LNG plant.

1.5 Implication of Natural Gas Introduction in Tanzania

In Tanzania, a substantial amount of natural gas is found in recent years, but its utilisation is still limited. Natural gas is expected to enhance economic development and improve quality of life. It is one of the important themes for the national energy policy how to promote utilisation of natural gas.

Energy consumption of Tanzania is around 10 million tons in oil equivalent (toe) in 2020; a half of it was used by the residential sector. Energy consumption will continue to expand reflecting population growth, economic development, modernisation of life, urbanisation, motorisation, etc., and will exceed 30 million toe by 2050.



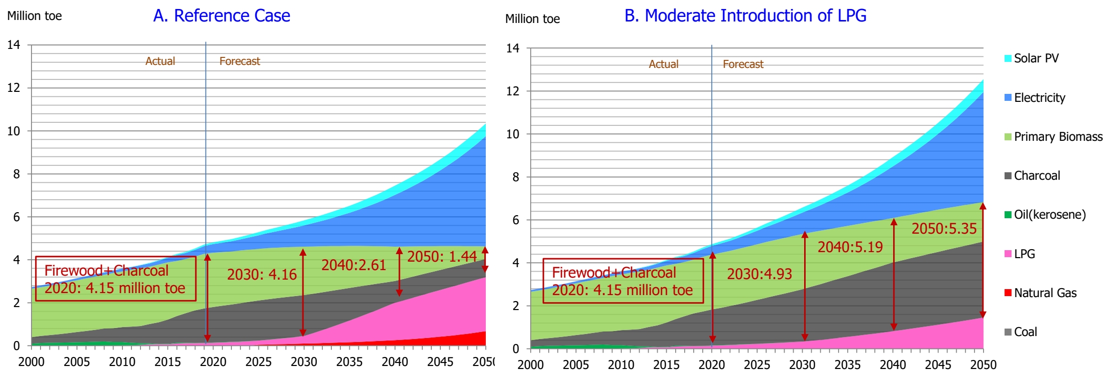
出所：JICA 調査団

Figure 1.5-1 Long Term Energy Outlook of Tanzania

Among others, traditional fuels such as firewood and charcoal comprise major part of the residential energy consumption (86.7% in 2020) causing problems such as domestic air pollution during cooking, deforestation, work for firewood collection, etc. In the Reference Case, we assume that natural gas and LPG will be introduced proactively increasing to 80% of the residential fuel consumption (on fuel efficiency equivalent3) by 2050. Then, consumption of firewood and charcoal combined will decrease to 1/3. As highly efficient gas stove is introduced, the total residential fuel consumption remains almost at the present level.

On the right graph (B), however, city gas is not introduced while LPG will penetrate but moderately from present 5% to 30% by 2050. Biofuel consumption will increase by 30% from present. Without remarkable improvement in energy efficiency, the total fuel consumption will also increase. In the country where forest degradation is serious, this would not be a sustainable scenario.

[3] Fuel efficiencies at use are assumed at 25% for firewood, 35% for Charcoal and 50% for gas.



Source: JICA Study Team

Figure 1.5-2 Firewood, Charcoal, Natural Gas and LPG Consumption: Residential Sector

Modern energies such as gas and electricity are essential for economic development and improving quality of life. Fortunately, substantial amount of natural gas is found in the country. With less GHG emissions compared with coal and oil, it is a preferable energy to cope with climate change. Utilisation of indigenous resource will also curb foreign currency outflow for import of petroleum products. Benefits are there. Our task is to establish a method how to deliver natural gas to relatively small domestic markets distributed over the vast land.

1.6 Case Setting: Gas Demand Development Scenarios

In order to find a realistic project size for the regional gas supply system, the Regional Energy Demand Survey was conducted in 2018. As discussed in Chapter 5, however, energy consumption in the industrial and services sectors in the regional cities turned out to be too small and could not justify immediate construction of a city gas system in any of the objective cities. In this context, the Study team decided to consolidate all prospective gas demands in the object regions into one project, and set out two cases as below for the Part-1 study to examine the difference in the project size.

Case-A: Reference Scenario

a. Gas demand at the city gas network to be developed at the New Government City (NGC) under construction in Dodoma
b. Direct bulk delivery to large industrial users in the objective five cities (Morogoro, Dodoma, Tanga, Arusha and Moshi but yet to research and include those in peripheral areas of Dar es Salaam.)
c. Gas sale as automotive fuel for NGVs

Case-B: Optional Scenario in addition to Case-A

a. Additional city gas development in the Dodoma city centre and Iyumbu Satellite Centre
b. Gas switching of the Zuzu power station presently using diesel gas oil
c. Co-generation (CHP) at new buildings within the city gas network

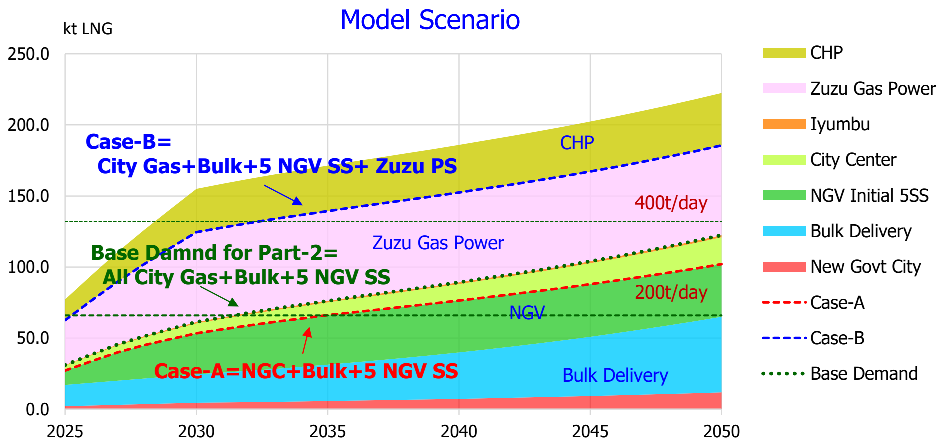
In Case-A, it is assumed that three city gas grids will be developed in Dodoma at the New Government City (NGC) being developed in Ihumwa, 17km east of the city. In case that natural gas is supplied as LNG or CNG, large industrial users identified by the Regional Energy Demand Survey in the objective regions but outside the reach of pipeline network will be supplied by direct bulk transport. In addition, NGV Service Stations will be built to supply natural gas as automotive fuel. Two stations will be built in Dodoma and three more along the route from Dar es Salaam to Dodoma at first. The NGV service station network will be expanded and amplified with time.

In developing a greenfield city gas project, it is necessary to establish a core market or a line-up of users that can provide an anchor demand. To this end, Case-B considers, in addition to city gas construction at the Dodoma city centre and the Iyumbu Satellite City, gas switching of the Zuzu thermal power station and adoption of co-generation systems at new buildings. Zuzu is an aging small power station using diesel gas oil as fuel and presently operated as a peaker; its generation cost is high and hence it is operated at a very low load. However, as a substation is located next to it, it is not necessary to newly construct the power transmission system after the upgrade. Renewal of the Zuzu power station will significantly improve the electricity security in the capital of the nation. In addition, the central line of the Tanzanian Railway runs nearby the location, which will allow use of railway for transport of gas containers in the future. Thus, Zuzu is considered as an advantageous location for the optional study.

Co-generation system (CHP: combined heat and power) is widely developed at buildings as well as regional systems in modern cities where certain demands for heat (hot and cold) and electricity co-exist. A CHP system utilises energy in a cascade flow and materialises high energy efficiency of 70-80% as discussed in Chapter 5. At business/commercial facilities, electricity is usually used to supply heat and power. If electricity is supplied by gas-based CHP, it would offer certain amount of gas demand as well as highly efficient use of gas. However, CHP is considered only for the optional case because the demand for heat would not be large in Dodoma considering the mild climate and the difficulty for CHP to compete with low grid electricity prices in Tanzania.

In Case-A, the total gas demand starts at about 25,000 tonnes in LNG equivalent in 2025, and exceeds 60,000 tonnes per annum by 2033, provided that construction of the NGC progresses as planned. If the popularisation of city gas advances in urban districts of Dodoma City, and the energy requirements of industries and other large users of bulk transport grow in the surrounding areas, the annual demand will expand to 100,000 tonnes by 2040.

In Case-B wherein the Zuzu Power Station is converted to a gas-fired plant and CHP is introduced at new buildings, the total gas demand will start at some 72,000 tonnes in 2025 and increase to over 140,000 tonnes by 2030.



Source: JICA Study Team

Figure 1.6-1 Potential Gas Demand for the First Virtual Pipeline System

Based on the above estimated gas demand, the following are used as the hypothetical plant size for the respective study cases:

Case A: Natural gas supply facilities capable of supplying 100 tonnes/day of LNG equivalent x 2 trains; with operation of 330 days/year, annual supply capacity = 66,000 tonnes

Case B: Natural gas supply facilities capable of supplying 200 tonnes/day of LNG equivalent x 2 trains; with operation of 330 days/year, annual supply capacity = 132,000 tonnes

In case of constructing a pipeline, it is assumed that gas may be transported up to its full capacity, which is 90,000 tons/year in LNG equivalent for a 12” pipeline and 323,000 tons for a 20” pipeline. In both cases however, the demand along the pipeline does not reach its capacity before 2050. This means that it is difficult to adjust the transport capacity of a pipeline flexibly.

1.7 Virtual Pipeline by way of mini-LNG

Under the model setting as above, economics is assessed on gas transport methods by way of pipeline, LNG and CNG. It is assumed that the feedgas is obtained at the Kinyerezi gas terminal in Dar es Salaam, where natural gas is supplied via the trunk pipeline from the Songo Songo and Mnazi Bay gas fields and is available at a price of $5.36/MMBtu as announced by EWURA. Then the gas cost is calculated on each method. It is the cost of gas transported to a satellite terminal in Dodoma and ready for supply into the city gas network. To be equitable, following two points are considered:

a. LNG must be regasified at the satellite terminal.
b. In case of LNG and CNG, one-week stock must be kept at the satellite terminal to assure stable supply against any surface transport disruption due to heavy weather, accidents, etc.

As discussed in Chapter 8, with the small gas demand projected, the gas transport costs by a fixed pipeline of 12” or 20” are significantly higher than those by the virtual pipelines such as LNG and CNG.

Table 1.7-1 Cost for Gas Transport

Vehicle		Mini-LNG		CNG		Pipeline	
Demand Scenario		A	B	A	B	A	B
Capacity : LNG equivalent		100t/d	200t/d	100t/d	200t/d	12"	20"
Train/line		2	2	2	2	1	1
Annual LNG Equiv.	tons/year	66,000	132,000	66,000	132,000	90,000	323,000
Gas Quantity	MMcf/year	3,188	6,377	3,188	6,377	4,354	15,613
	MMcfd	9.7	19.3	9.7	19.3	13.2	47.3
Demand							
Start Demand	tons/year	28,000	64,600	28,000	64,600	27,940	62,000
Reach peak in year	in year	2035	2033	2035	2033	after 2050	after 2050
Number of trucks required		20	44	46	105		
Stroage		400kl x 2	3,000 x2	46 containers	335 containers		
Gas Price		$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu
Feedgas Price		5.36	5.36	5.36	5.36	5.36	5.36
Plant processing		**8.34**	**5.89**	**2.33**	**1.94**	Included in transport	
Ex-plant Price		**13.70**	**11.25**	**7.69**	**7.30**	**5.36**	**5.36**
Transport		**1.62**	**1.49**	**3.44**	**3.46**	**46.16**	**17.83**
For Dodoma		**1.96**		**4.24**			
For Morogoro		0.97		2.04			
Satellite Terminal		**1.37**	**1.31**	**3.50**	**4.40**	**0.32**	**0.30**
Conversion+Transport		**11.34**	**8.68**	**9.27**	**9.80**	**46.48**	**18.13**
Ex- Dodoma Satellite Price including Feedgas Cost							
	$/MMBtu	**17.04**	**14.51**	**15.43**	**15.94**	**51.84**	**23.49**
	$/toe	676	576	612	632	2,057	932

Source: Tokyo Gas, Ishii Iron Works, Heritage Gas

Figure 1.7-1 Gas Storage Tanks by Type

Then, in comparison of LNG and CNG, LNG is selected because of the following reasons.

CNG at a high pressure of 25 MPa (250kg/m^2 or compressed to 1/250) can be contained only in specially designed narrow tubes. Otherwise, the gas may be stored in large spherical tanks at a pressure lower than 1 MPa (10kg/cm^2 or compressed to 1/10). In contrast, LNG can be stored at an ambient pressure while the gas is compressed to 1/590 when liquefied. To store the gas at Satellite-A equivalent to 800KL of LNG in combined CNG tube containers carrying 7.5 tons of gas, 46 containers are necessary. If a 4,000KL gas tank is adopted, 12 gas tanks are necessary.

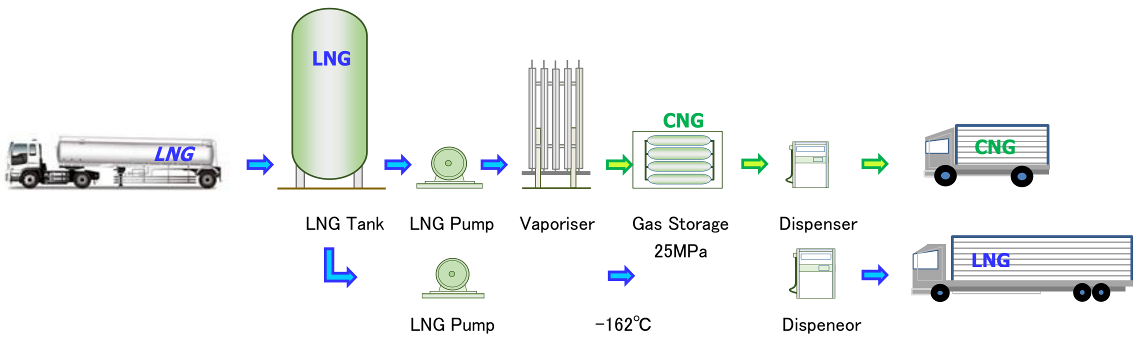
These are too costly and apparently impracticable.

Table 1.7-2 Storage Capacity for 7-days Stock

	LNG Tanks (KL)					Equivalent to LNG tanks: CNG Containers (Units)		Equivalent to LNG tanks: 4000kl Gas Tanks (units)	
	Size	2025	2030	2025	2030	2025	2030	2025	2030
	KL			KL	KL				
A: NGC	400	1	2	400	800	23	46	6	12
B: Zuzu	400	1	2	400	800	23	46	6	12
C: Iyumbu	60	1	1	60	60	4	4	1	1
Total		3	5	860	1660	50	96	13	25
B with PS	2500	1	2	3000	6000	171	342	44	89

Source: JICA Study Team

LNG is also superior to CNG in supply of auto-gas for natural gas vehicles (NGVs) in that an LNG-based gas station can supply both LNG and CNG. As discussed in Chapter 10 and 11, CNG is mainly used for light duty vehicles such as passenger cars and light trucks while LNG is increasingly used for heavy duty trucks and buses. A heavy duty truck can run 700-1,000km with LNG while 300-500km with CNG without refuelling. As a vast land country, Tanzania needs long distance haul by surface transport, and hence LNG-based automotive gas supply system is considered as a preferable option.



Source: JICA Study Team

Figure 1.7-2 L-CNG Station

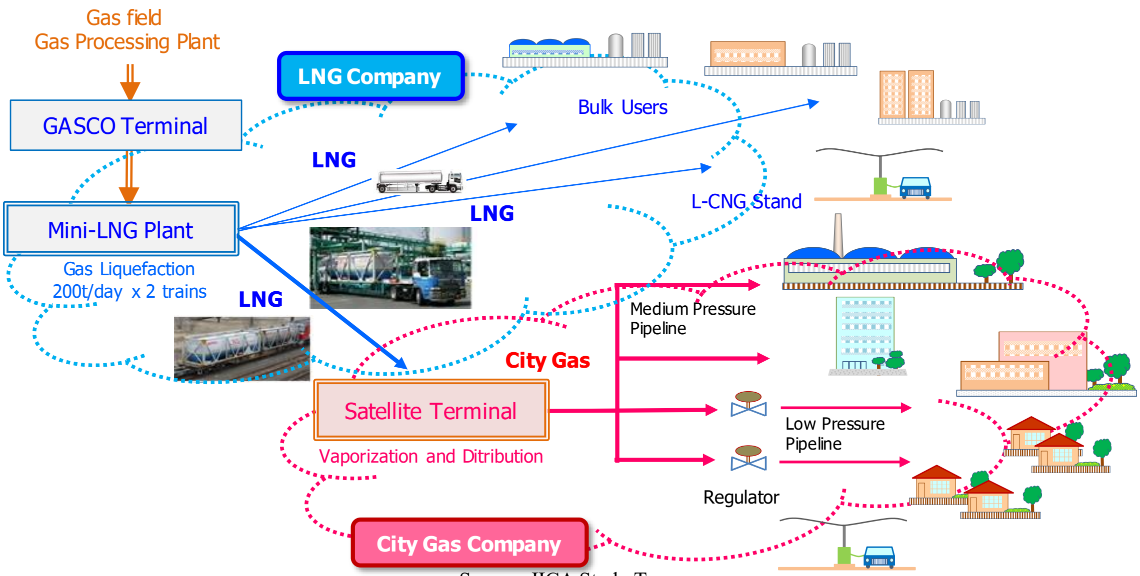
Based on the above analysis, LNG is selected as a suitable method to deliver natural gas to the regions where demand is small and gas supply systems are yet to be extended. Consequently, an Implementation Plan of an LNG-based model project is considered in Part-2.

1.8 Implementation Plan and Economics

Following the analysis in Part-1 Study, a model project plan for formulation of the Implementation Plan is set out as follows.

a. A mini-LNG plant will be built at the Kinyerezi energy complex in Dar es Salaam with

2 trains of 200 tons per day production capacity. Assuming 330 days operation a year, the annual LNG supply capacity will be 132,000 tons.



Source: JICA Study Team

Figure 1.8-1 Virtual Pipeline by mini-LNG

b. As the Base Demand Case, LNG will be supplied to three city gas systems in Dodoma at the New Government City, Dodoma city centre and Iyumbu Satellite Centre, about 20 large energy users and five auto-gas stations in the north-eastern regions of the country. This scenario assumes a slightly higher demand than that for Case-A in the Part-1 study in that all the three city gas plans are included.

a. As an optional case for High Demand, gas switching of the Zuzu Power Station or introduction of CHP (combined heat and power) system is considered.

1.8.1 Investment Amount

The investment required up to 2030 for the Base Demand Scenario of the mini-LNG based virtual pipeline system is estimated as shown in Table 1.8-1. The investment schedule may slip some years from this projection as shown in Figure 1.8-3.

The construction cost of the mini-LNG plant is biggest among the cost items. The second biggest cost item is the construction cost of the city gas network. It should be noted that the city gas construction cost is incurred only for city gas users, while the LNG plant cost is shared by all sectors. Considering that only 20% of the LNG is supplied for the city gas, and thus the 20% of the plant cost or $29.5 million is allocated for the city gas sector, construction cost of the city gas system at $42 million is significantly large.

For Satellite-B located at Zuzu, the storage tank capacity is assumed to be 400 KL x 2 for the Base Demand case. However, if Zuzu power station gas switching were considered, it should be ramped up to 3,000 KL x 2. This will push up the total investment by more than 10%.

Table 1.8-1 Investment Amount for Virtual Pipeline System

Stage	Preperation			Construction			Upfront	Production	Total	
Year	2019	2020	2021	2022	2023	2024	Total	-->2030	up to 2030	
	$ million	$ million	$ million	$ million	$ million	$ million	$ million	$ million	$ million	%
LNG Plant (200t/d x 2 trains)										
Feasibility Study	1.0						1.0		1.0	0.5
Marketing	0.3	0.3	0.3	0.3	0.3	0.3	1.8		1.8	0.8
Construction				15.0	50.0	75.0	140.0		140.0	63.1
Administration	0.8	0.8	0.8	0.8	0.8	0.8	4.8		4.8	2.2
Total	2.1	1.1	1.1	16.1	51.1	76.1	147.6	0.0	147.6	66.5
Transport										
Vehicles						1.4	1.4	8.6	9.9	4.5
Administration					0.3	0.3	0.5		0.5	0.2
Total					0.3	1.6	1.9	8.6	10.4	4.7
Satellite (A+B+C) without Zuzu Power station										
Construction				0.1	1.5	3.0	4.6	2.2	6.8	3.1
Administration				0.1	0.1	0.1	0.3		0.3	0.1
Total				0.2	1.6	3.1	4.9	2.2	7.1	3.2
City Gas Network (A:NGC+B:City Centre+C:Iyumbu)										
Construction				0.3	9.0	27.0	36.3		36.3	16.3
Administration				0.9	1.5	2.9	5.3		5.3	2.4
Total				1.2	10.5	29.9	41.6		41.6	18.7
Connection Cost						6.8	6.8	8.5	15.3	6.9
LNG Supply Company	2.1	1.1	1.1	16.1	51.4	77.7	149.5	8.6	158.0	71.2
City Gas company				1.4	12.1	39.8	53.3	10.7	64.0	28.8
Total	2.1	1.1	1.1	17.5	63.5	117.5	202.8	19.3	222.0	100.0
Satellite (A+B+C)										
with Zuzu Power Plant				0.6	3.6	11.1	15.3	13	28.3	12.7

1.8.2 LNG Plant

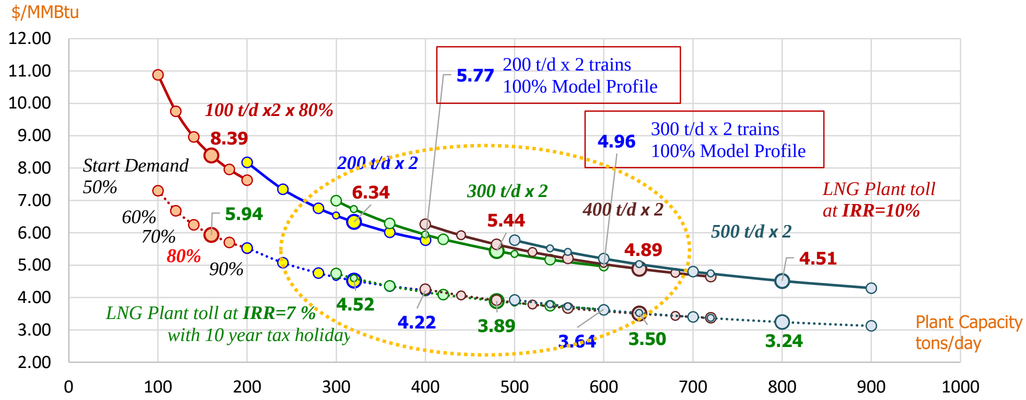
The LNG plant toll required to bring economics at IRR=10% is calculated as shown in Table 1.8-2. Assuming the Base Demand Scenario, the required toll becomes very high as the plant utilisation ratio for the whole project period remains merely at 60%. If the plant is highly used, it goes down dramatically.

Table 1.8-2 LNG Plant Toll

Sector	Base Demand		High Demand	
	City Gas+Bulk+NGV 5 SS		plus Zuzu PS	
	$/MMBtu	$/toe	$/MMBtu	$/toe
LNG Plant Toll	9.89	392	5.89	234
Daily Prodcution	242	tons/day	372	tons/day
Plant utilisation	60.5	%	93.1	%

Source: JICA Study Team

In order to understand effect of LNG plant size and utilisation rate, more moderate cases are examined as shown in Figure 1.8-2. It is apparent that the plant size and utilisation rate affect the plant economics significantly, and that a smaller plant cannot achieve a lower cost even utilised 100%. From this calculation, suppose certain demand is secured by enhanced marketing efforts, the LNG plant cost may be reasonably assumed at around $6.00/MMBtu.



Source: JICA Study Team

Figure 1.8-2 LNG Plant Toll by Plant Size and Utilisation

1.8.3 Natural Gas Delivered Price

In addition to the above, tolls required to materialise IRR=10% are estimated by sector. They are \$1.70/MMBtu for LNG transport to Dodoma, \$1.80/MMBtu for the satellite terminal, \$2.00/MMBtu for bulk users and \$3.00/MMBtu for auto-gas station as summarised in Table 1.8-3. Tolls or costs incurred in these sectors are relatively small.

Adding up these, the burner tip price of natural gas at direct delivery bulk users is estimated to be \$17.06/MMBtu and the pump price for NGVs \$16.06. Compared with imported petroleum products except for heavy fuel oil, they are significantly lower. Delivery of natural gas by way of virtual pipeline is a very attractive option. However, we should note that users must convert their facilities or vehicles for use of natural gas which requires upfront expenditure and technical services.

On the other hand, additional investment is necessary to construct the city gas system for distribution of natural gas by pipeline. The toll required for the city gas system is high for the Base Demand case where individual customers are relatively small such as general office buildings, small shops and households and resultantly the total gas demand is limited. However, if some large users such as office buildings with CHPs are added and provide some base demand, the fixed cost will be diluted and the required toll goes down dramatically. As the demand size affects the city gas economics significantly, it is foremost important to recognise the size of the affirmative demand for the project.

From the calculation shown in Table 1.8-3, for the city gas to be attractive compared with LPG, unit cost at the city gas sector needs to be lowered, say by \$3.00-5.00/MMBtu or 10-20 cents per kg oil equivalent by introducing large users or providing some supporting fund.

Table 1.8-3 Natural Gas Delivered Price

	Bulk Users		NGV Stations		City Gas		City Gas + CHP		Target	
	$/MMBtu		$/MMBtu		$/MMBtu		$/MMBtu		$/MMBtu	
Feedgas Price	5.36		5.36		5.36		5.36		5.36	
LNG Plant	6.00		6.00		6.00		6.00		6.00	
Transport for Dodoma by container	1.70		1.70		1.70		1.70		1.70	
SatelliteTerminal					3.00		1.81		1.80	
Satelllite (receiving and vaporisation)	4.00									
NGV Station			3.00							
Virtual Pipeline	11.70		10.70		10.70		9.51		9.50	
Sub-Total	**17.06**		**16.06**		16.06		14.87		14.86	
City Gas System					18.47		6.63		8.00	
Connection					2.53		0.83		2.00	
Total City Gas					**21.00**		**7.46**		**10.00**	
City Gas Promotion Levy	**5.00**									
NGV Fund	0.20	$/kg	**5.00**							
Delivered Gas Price	**22.06**		**21.26**		**37.06**		**22.33**		**24.86**	
Oil 10,000 kcal/kg	0.88	$/kg	0.84	$/kg	1.47	$/kg	0.89	$/kg	0.99	$/kg
Petrol 7,900 kcal/ltr	0.69	$/ltr	**0.67**	$/ltr	1.16	$/ltr	0.70	$/ltr	0.78	$/ltr
Diesel 8,600 kcal/ltr	0.75	$/ltr	**0.73**	$/ltr	1.26	$/ltr	0.76	$/ltr	0.85	$/ltr
Fuel Oil 9,700 kcal/ltr	0.85	$/ltr	0.82	$/ltr	1.43	$/ltr	0.86	$/ltr	0.96	$/ltr
LPG 11,300 kcal/kg	**0.99**	$/kg	0.95	$/kg	**1.66**	$/kg	1.00	$/kg	**1.11**	$/kg
Present Price in Dodoma	Comparison									
Petrol **1.08** $/ltr	64%		62%		108%		65%		72%	
Diesel **1.00** $/ltr	75%		73%		126%		76%		85%	
LPG **1.30** $kg	76%		73%		**128%**		77%		**86%**	

Source: JICA Study Team

In addition to the above, upfront cost for inlet-pipe connection will be a problem particularly for small users. For example, it will be $1,000-1,500 per house and people need to purchase gas appliances in addition. While the city gas is thought to provide clean fuel at reasonable price in the long run, financing the upfront expenditure such as the connection cost is the key to be overcome for its promotion.

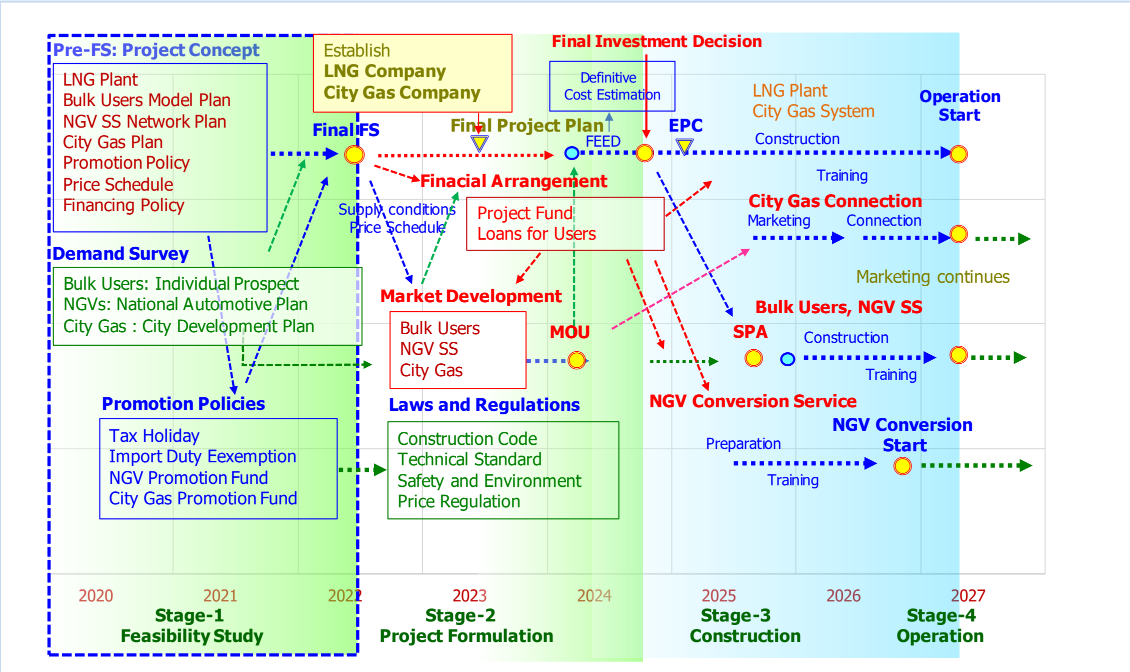
It should be noted that the above cost is estimated applying Japanese cost data as local data was not available. Civil work, which is cheaper in Tanzania than Japan, comprises a substantial part of city gas construction. The above cost estimation should be reviewed applying realistic local cost.

1.8.4 Roadmap

The roadmap for implementation of the DNGPP project may be as shown in Figure 1.8-3. At present the prospective demand is small and uncertain. To define the project, we must set out the grand design of natural gas utilisation at first. Demand sectors suitable for natural gas use may be as follows;

a. Fuel users in the dense-demand areas suitable for city gas grid development
b. Standalone large users and consolidated industrial parks for direct gas delivery by way of virtual pipeline (LNG/CNG)
c. New demand such as NGVs and rural electrification

On the other hand, potential gas users in sparse demand areas will be supplied with LPG because of the convenience and economy for small lot delivery. As discussed in Chapter 5, LPG demand will also grow robust exceeding half a million tons or more. As it needs to be imported from abroad, it is necessary to prepare international class large import facility to accommodate the domestic supply as well as transit cargoes for inland countries. In consideration of this, an LPG supply plan must be figured simultaneously. In addition, feedgas requirement for gas industry projects such as fertilizer and large scale LNG may be considered separately from the above.



Source: JICA Study Team

Figure 1.8-3 Roadmap for DNGPP

Once the grand design of natural gas utilisation and demand outlook is established as above, we should proceed with preparation of the supply side as follows;

a. A comprehensive plan of the natural gas supply chain including pipeline, LNG/CNG plant, transport, satellite and city gas system together with firm policies to decide their cost and schedule for toll.

b. LNG/CNG supply plan for direct bulk transport users including large users of heavy fuel oil with model plans on facility, cost schedule, technical service and financial support.

c. City gas development plan including, in addition to gas grid construction plan, price schedules for users, technical service and financial support for suppliers and users.

d. Automotive gas supply plan including policies to introduce NGVs, cost schedules for NGV users, technical service and financial support.

1.8.5 Major Concerns

Although the DNGPP as a whole looks viable, several issues must be clarified for finalisation of the project plan such as:

a. To decide the size of the project, in particular relating to the economics of the LNG plant and city gas system, it is necessary to confirm the prospect of affirmative demand. As a guideline to consider this, a comprehensive energy plan must be set out to show the future energy structure and the roles of natural gas and LPG.

b. In considering this, gas supply for large users presently using heavy fuel oil or petrocoke is an issue. To kick out these cheaper fuels, it is necessary to offer competitive prices cheaper than discussed above. In view that such bulk demand would offer economies of scale particularly for the LNG-plant sector, a deliberative investigation should be made on this matter.

c. For introducing natural gas, it is necessary to prepare technical services in the market for switching facilities, appliances or cars for gas use. Proper policies, laws and regulations must be set out to prepare the business circumstance for these services and develop supporting industries.

d. Viability of the city gas sector is questionable if the demand is small. Also, upfront expenditure for pipe connection, appliances and cars would be a hurdle for minor consumers. Appropriate policies need to be set out to solve these problems.

e. Introduction of natural gas vehicles will bring about substantial benefits in terms of environment protection and control of foreign currency outflow. However, the mobility policy must be decided with careful consideration on the global trend toward promotion of electric vehicles.

To set up a practicable project, it is necessary to set up a comprehensive plan with collaboration of wide range of ministries and other stakeholders.

1.9 Way Forward

Progress of natural gas utilisation is relatively slow in Tanzania. This may be partly caused by vague anxieties in the background as below:

1) Developing large natural gas projects such as gas fired power stations and an LNG project, natural gas resources would be used up after 30 years.

2) Is it a right way to increase fossil fuel consumption as the world is moving toward a net-zero society?

Firstly, Tanzania is still in an early stage of natural gas exploration. As seen in the history of foregoing countries, the natural gas resources can be increased with future exploration activities. Geological potential is high. If effective demand were created, active players will show up, explore for and develop the resource base[4].

Secondly, energy consumption of Tanzania is presently less than 2% of that of Japan while heavily depending on traditional biofuels such as firewood and charcoal. It is impossible to leapfrog from this status to a modern economy solely based on variable renewable energies. The right and practicable pathway is to establish modern energy infrastructure utilising natural gas at maximum, which is available, relatively clean and environment friendly, and then try to decarbonise it in future with introduction of modern biogas, methanation and/or construction of hydrogen network.

Since the Study Team reported the study outcome at the symposium held in January 2020, there have been several important developments such as;

a. Sizable new gas discoveries at Ntorya and Mambakofi, both onshore and close to the existing pipeline.
b. Power System Master Plan (PSMP) 2020 Update announced in September 2020, which schedules construction of gas power plants at Dodoma (600MW) in 2033 and Bagamoyo (300MW) in 2040.
c. Agreement signed with Kenya in May 2021 on construction of a new pipeline from Dar es Salaam connecting to Mombasa.
d. Baker Botts, a prominent international law firm, was nominated as the Transaction Adviser to the Government Negotiation Team and TPDC regarding the development of the LNG project. This will accelerate development of the long-waited LNG project.

The above developments suggest extension of gas pipelines to Dodoma and Mombasa supported by sizable demand, which in turn means significant change of the backbone pipeline system. On the other hand, with several surveys on potential gas demand, information is collected for eleven regions to date, while we need more information on the rest of the county to figure the grand design of the future gas demand. Under the circumstance, the Study Team recommends conduct of Framework Study to follow the roadmap shown in Section 1.8.4 above and formulate National Gas Development Plan incorporating the new developments. This will lead to effective utilisation of the natural gas resources and will make great contribution to development of Tanzania through modernisation of daily life and economy while curbing foreign currency outflow, GHG emissions and deforestation.

[4] According to the BP Statistical Review of World Energy, natural gas reserves in Malaysia was 19.7 Tcf in 1983 when the country began LNG export. By 2020, the country had consumed 63 Tcf of natural gas, while natural gas reserves at the end of 2020 increased to 32 Tcf; which do not include the resources under evaluation expected to be more than 10 Tcf.

Chapter 2 Trend in the World Gas Market

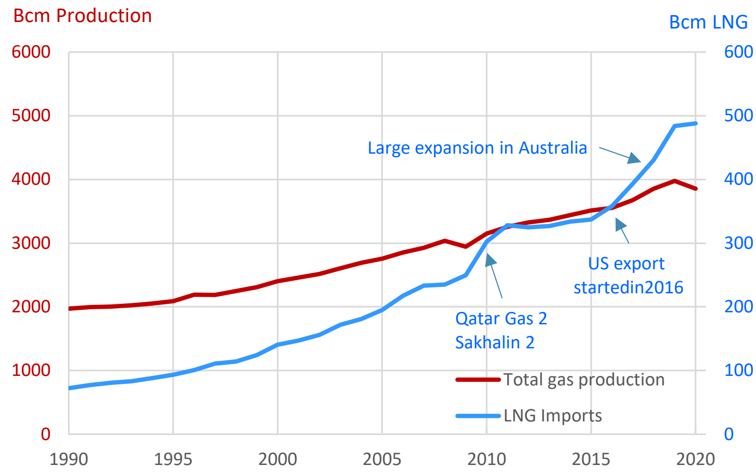
In this chapter, sections 2.1 through 2.3 were written in 2019 before Covid-19. We keep them untouched so that readers can compare them with the Post-Covid-19 analysis developed in sections 2.4.

2.1 Long term outlook of LNG demand and supply：Projection in 2019 before COVID-19

2.1.1 Overview

LNG demand in the world has shown a remarkable increase in the last two decades. It almost reached 314 million tonnes in 2018 while it was just above 110 million tonnes in 1997. While the LNG industry is relatively young, just celebrated its 50th year anniversary in October 2014 since its first cargo was shipped from Algeria in 1964, the industry will continue changing its shape and ever evolving.

The latest expansion phase of the LNG industry is featured with unprecedented transformation. Supply capacity increased dramatically between 2009 and 2011. Then, in the aftermath of the Fukushima Daiichi nuclear plant accident in March 2011, which prompted the shut-down of all nuclear power plants in Japan and mobilisation of relief thermal power plants to compensate for the loss, power companies were forced to scramble to secure LNG cargo additionally required to fuel the thermal plants. The traditional LNG transaction system assuming long term contract could not fully accommodate the new situation with significant expansion of demand and the wide discrepancies in location. New trading patterns such as *spot trading, short-term contract, arbitrage, equity lifting, and portfolio trading* are spreading widely in the global LNG trade scenes.



Source: Compiled by IEEJ based on data from BP Statistical Review of World Energy 2021, Cedigaz

Figure 2.1-1 Global LNG and Natural Gas Production：Updated

Since 2018, further evolution of trading patterns has been underway with significant increase in the global LNG supply capacity and the rise of emerging LNG importers such as China. During the on-going expansion phase, two production centres are increasing their presence: Australia and the United States. The wave of big project start-up is almost ending in Australia as Ichthys and Prelude FLNG projects, started up in 2018 and 2019, respectively. LNG from the United States will bring about another layer of flexibility and liquidity into the market being basically free from destination restriction.

On the demand side, LNG demand of emerging importers is more elastic to price level than that of traditional importers such as Japan and Korea and tends to prefer spot or short-term contract with volume flexibility. This is because the emerging importers have more energy supply options such as domestic production, pipeline import, coal, or even renewable energy, and LNG is regarded as a “balancing” energy source rather than the “baseload.” Such demand characteristics are urging the LNG producers to be more flexible in their LNG supply to secure markets.

2.1.2 Major producers and consumers

Then who are the major players in production, consumption, exports, and imports of natural gas and LNG? Figures 2.1-2 show the world’s LNG suppliers and consumers, respectively. On the supply side Qatar is by far the largest followed by Australia and Malaysia. Region-wise, the share of traditional Southeast Asian suppliers has waned while the presence of the Middle East and Australia has consistently grown. On the demand side, Japan has been the largest consumer for more than three decades. The demand of China has rapidly been expanding and the country surpassed Korea as the second largest LNG consumer in 2017.

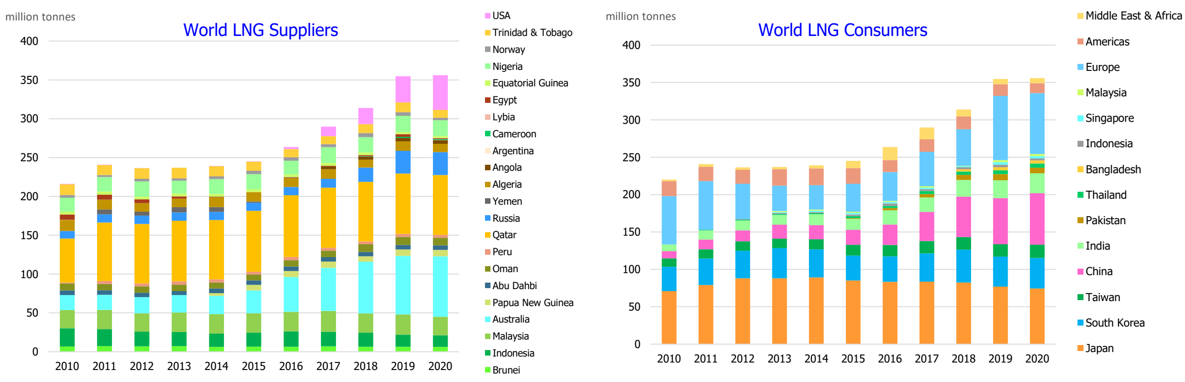


Figure 2.1-2 World LNG Suppliers and Consumers: Updated

2.1.3 Key factors in international LNG market

(1) Chinese demand

China is undoubtedly one of the major players that will shape the global LNG market in coming years. The country was the world’s second largest LNG importer in 2017 and 2018 only after Japan, and the country has already had a significant presence in the current international LNG market. In China, LNG represented 27%[5] of the country's total natural gas demand in 2018, yet natural gas accounted for only 7% of the total primary energy supply in China as of 2018.[6] These figures suggest that, despite its increasing presence and influence in the international LNG market, LNG supplies only 1.5% of the country's total energy supply. Because of this very small share, the demand for LNG in China has a significant potential.

China's future LNG demand is affected by various factors. The most significant one is the country's macro economy. Because, in China, natural gas is used mainly in the power and industrial sectors, both of which are more influenced by economic activities than the residential or commercial sectors, macro-economic conditions will affect the country's natural gas demand more evidently. Energy and environment policy is also an important factor. The surge in China's LNG imports in 2016 and 2017 is largely due to the government's policy to restrict coal consumption to address the air pollution problem in north-eastern parts of the country. Development of its natural gas resources also affects the natural gas balance of the country and thus the volume of LNG imports. Because China will need to develop more difficult gas including unconventional gas resources from now on, the speed and size of its future development of gas resources will become more uncertain.

(2) ASEAN Markets

ASEAN used to be a major LNG exporting region, but due to declining domestic natural gas production and increasing domestic energy demand, four ASEAN countries, notably, Indonesia, Malaysia, Singapore, and Thailand have started to import LNG. While it is forecasted that ASEAN as a region will continue to be a net natural gas exporter until 2030, it is likely that the region's LNG imports are expected to grow. We will discuss the LNG trend of ASEAN countries in Section 2.4 with latest updates.

(3) Demand growth in South Asia including India

South Asia is another driver for the future LNG demand growth in the world. As for India, the largest LNG users are oil refineries, followed by the fertilizer industry and industrial users. All of these users are very sensitive to prices as they have alternative energy sources besides imported LNG. LNG is also used for power generation, but due to regulated electricity prices under subsidisation policy, imported LNG is still not a preferred fuel.

LNG demand in other South Asian countries (Pakistan, Bangladesh, and Sri Lanka) has attracted considerable attention in Asia in the past few years as the region has a significant potential of LNG demand. We will discuss the LNG trend in this region in Section 2.4 with latest updates.

[5] Based on NDRC and Customs Statistics data
[6] BP Statistical review of World Energy 2019.

(4) Qatari expansion

Qatar is a major supply-side player that affects the future balance of the world LNG market. While the country had adopted moratorium for new liquefaction capacity development since 2005, it announced in April 2017 that it lifted the moratorium and plans to expand its liquefaction capacity from the existing 77 million tonnes per year to 100 million tonnes per year by 2024. This capacity expansion will certainly strengthen its presence and influence on the world LNG market in the future. The expansion project is expected to be a package of debottlenecking of the existing trains and new train construction. Japan's Chiyoda Corporation has been awarded a FEED study of the debottlenecking projects. We will discuss the recent status of the Qatar expansion in Section 2.4.

(5) Surge of US LNG supply

The United States is one of the oldest LNG suppliers in the world. Its LNG export from Alaska greatly contributed to the development of the early stage of LNG market development in Asia. Backed by the significant expansion of natural gas resource base and its production, the country shipped the first LNG export from Lower 48 states in February 2016 and its supply capacity will reach about 60 million tonnes per year by 2020.

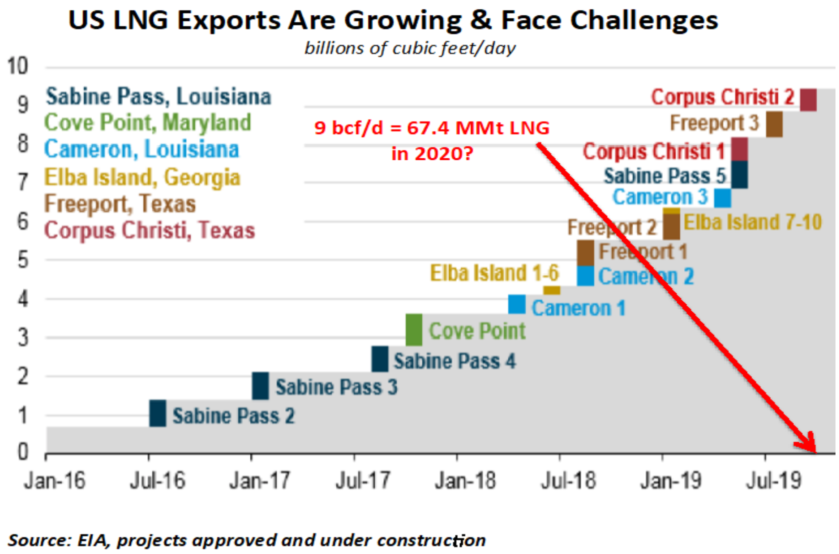
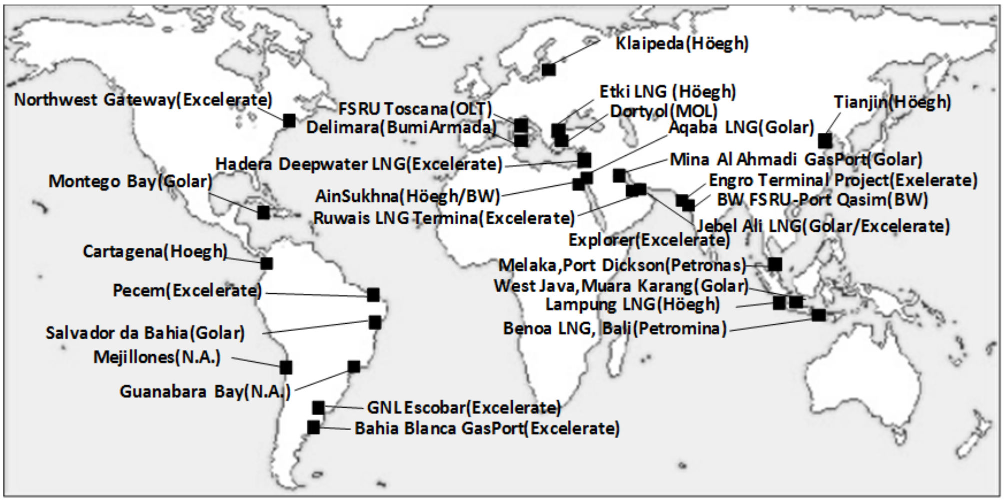


Figure 2.1-3 US LNG Export Capacity Outlook

The US LNG supply has a potential of bringing about a significant change in both the physical supply and demand balance and the trading pattern of the world LNG market. Its rapid expansion of supply capacity, which stands at around 18 million tonnes per year at the end of 2017, has already provided a new source of supply around the world and aggravated the supply surplus since 2014. The scheduled supply capacity expansion will also have an effect in prolonging the current surplus balance well into the 2020s. One peculiar aspect of the US LNG is its flexibility. Unlike the traditional LNG supply, it does not have a destination restriction and can be resold to other parties depending on the market condition. This flexibility will activate the spot trading of LNG cargoes, and change the current pricing practice based on the crude oil price by creating a more transparent benchmark. Such a change of pricing practice can take time, but it certainly has a possibility to cause a structural change in the LNG market.

(6) Adoption of floating technologies

Floating liquefaction and regasification technologies is expanding its applications in the international LNG market. Floating liquefaction is, as it suggests, a liquefaction facility on a floating object. RFSU (Floating Storage and Regasification Unit) is an LNG receiving and gasification facility to serve as a receiving terminal at a consumption point. Both floating technologies have significantly contributed to promotion of LNG in the recent years. We will discuss on recent development in Section 2.4.



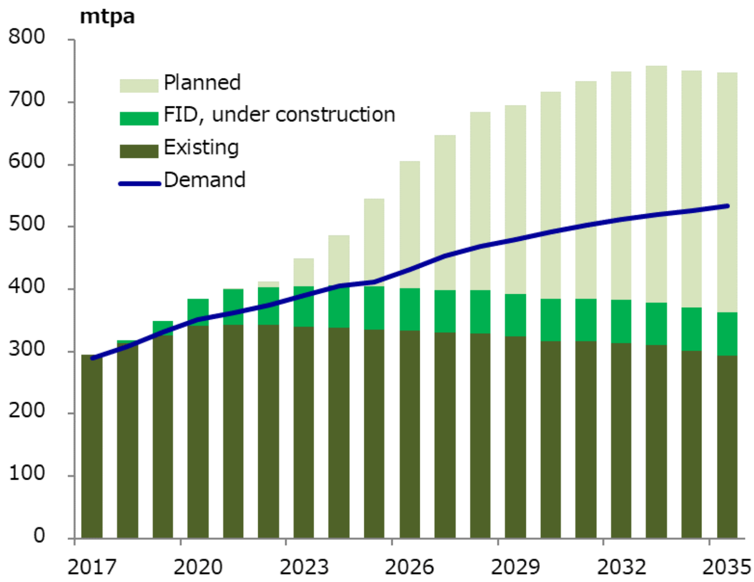
Source: Compiled by IEEJ based on publicly available information

Figure 2.1-4 FSRU Projects in the World

2.1.4 Long-term LNG demand and supply balance

Based on the above observations and the world energy outlook provided by the Institute of Energy Economics, Japan (IEEJ)[7], Figure 2.1-5 shows the long-term LNG demand and supply outlook. The LNG demand is estimated by IEEJ from the assessments of natural gas demand, natural gas production, and pipeline trade in the existing and future LNG importing countries. The world LNG demand is expected to exceed some 350 million tonnes by 2020 and 500 million tonnes by 2030. Supply is estimated by adding on top of the existing liquefaction capacity, projects under construction, those after final investment decision (FID), and planned capacity that waits FID. The sum of existing and FID, and under construction capacities, or the firm capacity, will be around 400 million tonnes in 2020; but will gradually be declining toward 2030.

[7] The Institute of Energy Economics, Japan, *IEEJ Outlook 2018* (October 2017)



Source: IEEJ Analysis

Figure 2.1-5 Long-term LNG Demand and Supply Balance up to 2030

The firm capacity will exceed the demand until the mid-2020s, which suggests surplus supply balance will continue for short and mid-term. After the mid-2020, however, demand will overtake the firm capacity, and the market may become tight in case the planned capacity is not realised sufficiently. In 2016 and 2017, only one and two FIDs were realised, respectively, due to lower international oil and gas prices. Three FIDs, representing 21 million tonne per year capacity were made in 2018. So far in 2019 by June, also three FIDs, representing 33 million tonne per year capacity, have been already announced, potentially followed by many other projects expecting investment decisions later in the year. Timely FID and swift realisation of the planned liquefaction project is desired.

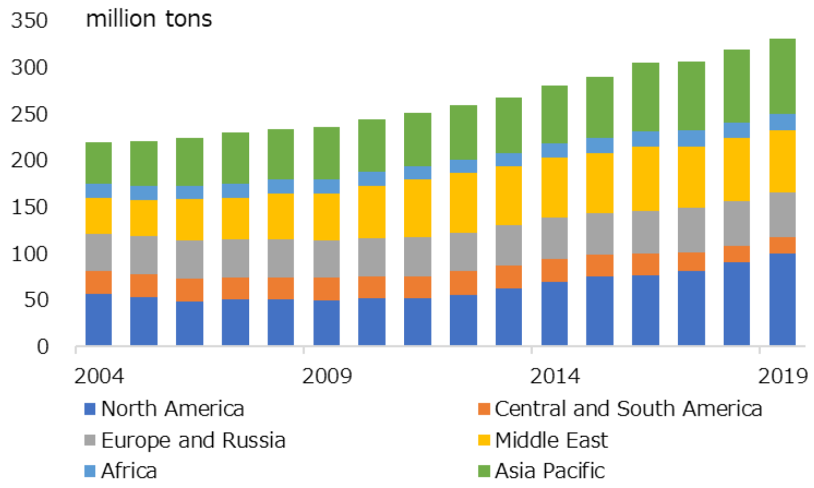
2.2 Long term outlook of LPG market

2.2.1 World LPG demand and supply

Liquefied petroleum gas (LPG) is petroleum gas mainly composed of propane (C_3H_8) and butane (C_4H_{10}) and is liquefied by pressurising under the normal temperature. LPG is a completely different fuel from LNG that is mainly composed of methane (CH_4). LPG can be produced from gas processing at oil and natural gas fields and from refining process of crude oil. LPG can be liquefied either by pressurising or refrigeration under much milder condition compared to LNG. It is much more easily liquefied and thus easier to handle. LPG is usually used in residential, commercial, and petrochemical sectors (as feedstock). LPG is transported and stored in liquid form.

(1) World LPG supply

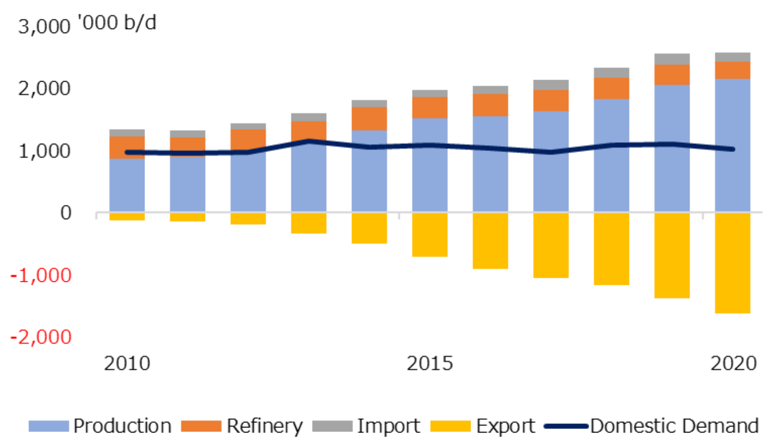
More than 60% of the world LPG is supplied from associated production from oil and gas fields, and the remaining 40% is produced from oil refining process. The world LPG supply as of 2016 was 331 million tonnes.



Source: Argus Consulting Services, Statistical Review of Global LP Gas 2020

Figure 2.2-1 World LPG Production

Region-wise, North America produces the largest volume of LPG (100 million tonnes) followed by Asia Pacific (81 million tonnes), the Middle East (66 million tonnes), and Europe and Eurasia (48 million tonnes). Production in North America has shown a significant growth since the early-2010s thanks to the Shale Revolution. Most of tight oil is light in its quality and tends to contain a large amount of LPG. In Asia Pacific, China and Australia are leading the regional production. Production growth in China has been observed both in upstream oil and gas field production and production from refining process at refineries. Most of the LPG supply in Australia is associated products at LNG plants. Production in the Middle East has been driven by natural gas and crude oil production growth in Saudi Arabia, UAE and Qatar.



Source: U.S. Energy Information Administration

Figure 2.2-2 LPG Supply in the U.S.

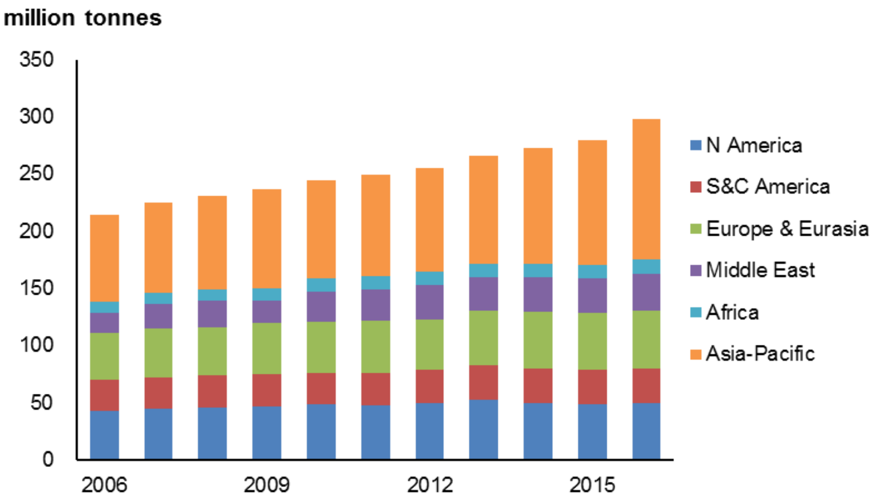
Among the major LPG producers, the United States is the largest contributor to the supply growth in the last decade. Upstream production is the largest component of the LPG supply in the United States as shown in the Figure 2.2-2. Significant contribution is made by associated gas resulting from the rapidly increasing light tight oil production. Because the domestic LPG demand in the United States has been almost flat since 2012, most of the incremental supply has been exported.

Production from 2015 to 2016 somewhat stalled due to the fall in domestic oil and natural gas price, but it recovered the growing trend in 2017.

In 2020, because of the price impacts of COVID-19, the domestic production growth slowed down, but the export increased because the U.S. domestic demand declined.

(2) World LPG demand

World LPG demand has steadily grown from 2006 to 2019 as shown in Figure 2.2-3. The largest demand growth was observed in Asia Pacific. The region's demand has grown 1.6-fold during the same period. China and India are the two major markets whose demand has grown significantly. Residential and commercial sectors are the primary demand sectors in these countries. In China demand for petrochemical feedstock for Propane Dehydrogenation (PDH) process has also gradually increased reflecting its price competitiveness over other oil products. The growth rate used to be large in the Middle East, but the speed of the growth declined in recent years.



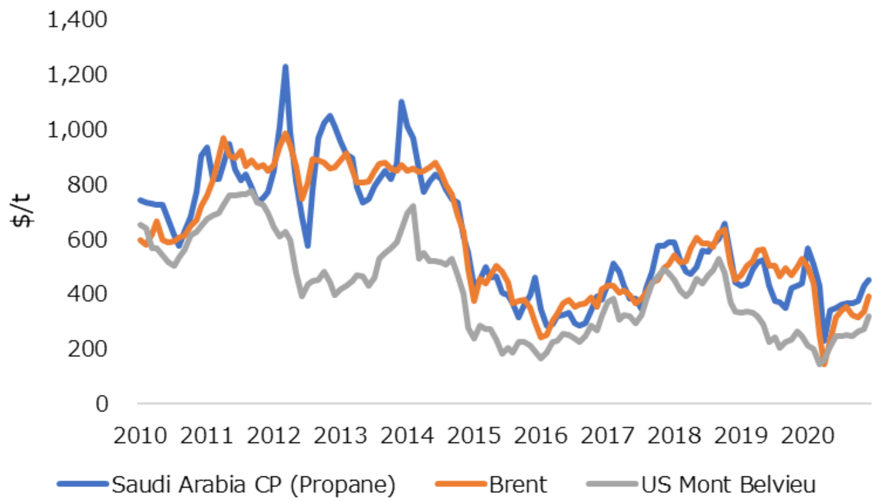
Source: Argus Consulting Services, Statistical Review of Global LP Gas 2020

Figure 2.2-3 World LPG Demand

2.2.2 World LPG prices

International LPG prices move in a similar pattern to international crude oil price as shown in Figure 2.2-4. This is because the term contract price set by Saudi Arabia is determined based on international crude oil price, and other LPG exporters follow the pricing of Saudi Arabia as its influence on the market is large. Spot contract prices are also affected by the term contracts as

LPG importers always compare the term contract price and the spot market level. When the U.S. production rapidly grew from 2013 to 2014, it was considered that the rise of the U.S. production will decouple the LPG price from the crude oil price. LPG benchmark price in Mont Belvieu was actually traded at far lower level than the crude oil price level. But in recent years, such decoupling has not occurred and the LPG price and crude oil price rather have converged probably because of arbitrage effects through increased exports.



Source: Japan LP Gas Association, U.S. Energy Information Administration

Figure 2.2-4 LPG Prices and Crude Oil Price

LPG prices are usually higher than crude oil prices; but since the crude oil price fall in 2014 and pressing production increase in the United States, the price differential between crude oil and LPG has narrowed down. Spot price in particular has become almost equivalent to crude oil price reflecting the soft market condition of the international LPG market.

Both propane and butane prices are influenced by crude oil price, while there are also different factors that affect the price dynamics of the two LPGs. Butane price is usually higher than propane price reflecting its higher calorific value vis-a-vis propane. Butane price is more affected by crude oil or oil product price because butane is often used as a blending component for motor gasoline and as a substitute of naphtha for petrochemical feedstock. Use of butane has more linkage to oil product and thus butane price tends to have higher correlation with crude oil price. While propane is also used as petrochemical feedstock particularly to produce propylene, its main use is residential and commercial fuel and has smaller linkage to oil product consumption.

2.2.3 Long-term LPG outlook

(1) Demand

On demand side, a major source of demand growth will be undoubtedly emerging countries, particularly in Asia Pacific and the Middle East. Steady economic growth in these regions will increase energy demand in all sectors. For residential and commercial use, LPG is an attractive energy as it does not need a sizable upfront investment like pipeline network, and it is much cleaner than conventional biomass energy, and also convenient to use (portability, quick to ignite, etc.). As the income rises, people will prefer to use a cleaner and convenient energy source such as LPG over conventional biomass.

Among major LPG markets, China will remain as a key location to determine the market demand and supply balance. As in the historical development, residential and commercial sectors will be the major demand segments in the country. Since 23% of residential energy demand is still supplied by conventional biomass in China as of 2019, demand growth potential for LPG is significant. Besides residential and commercial demand, petrochemical feedstock is another use of LPG in China. While butane is usually a favoured petrochemical feedstock for ethylene cracker, a large volume of propane is also utilised as a feedstock for PDH plants, which produces propylene by removing hydrogen from propane. As of June 2017, eight PDH plants are in operation according to ICIS.[8]

In India, residential and commercial sector will be the primary sectors where demand growth will be observed. Unlike China, LPG demand for petrochemical sector will be limited due to smaller petrochemical capacity. LPG price is regulated by the government as of October 2018 and, moves related to this regulation policy will influence the competitiveness of LPG against other energy sources.

In the Middle East, because the population is smaller and its climate is warmer compared to emerging Asian countries, the magnitude of the demand growth to the total demand may seem limited. Yet, the rate of population growth in the region is significant and there are a number of newbuilding and expansion plans for petrochemical manufacturing capacities. Strong demand growth in residential, commercial, and petrochemical sector is expected in the Middle East.

Sector-wise, residential and commercial sectors will remain as the dominant users for LPG. Demand for LPG in petrochemical sector is more elastic to price level than the demand for the above two sectors since LPG can be substituted by petroleum product such as naphtha or other petroleum-based feedstocks depending on the relative price level.

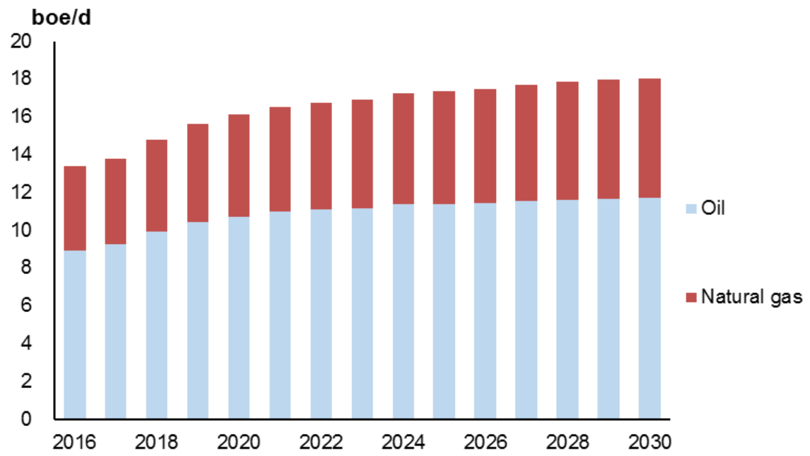
The market balance in the international LPG market is expected to be soft in the short-to mid-term, and more LPG may be used in petrochemical sector as far as supply surplus exists in the market. In total, the world LPG demand is likely to grow to 350 to 400 million tonnes by around 2030. Factors that affect the level of demand will be crude oil price, relative price of LPG against petroleum products, macro-economic conditions in emerging countries, and the demand for petrochemical feedstock. Growing interests in the decarbonization in recent years is not likely to

[8] "No new China PDH projects coming on stream in 2017-2018," ICIS News (6 June 2017) (https://www.icis.com/resources/news/2017/06/06/10112939/no-new-china-pdh-projects-coming-on-stream-in-2017-2018/) accessed on 26 April 2018.

affect the growth of LPG demand because such demand growth of LPG will occur mainly in the residential sector in rural areas and in the petrochemical sector where outright adoption of renewable energy is not easy.

(2) Supply

On the supply side, North America, particularly the United States, will lead the growth in the future. Although the growth in the region backed by Shale Revolution is expected to slow down after 2020, the United States will continue to be the largest LPG supplier in the world until 2030. Because one Canadian LNG project (LNG Canada) reached FID in September 2018, production growth from Canada is also expected.



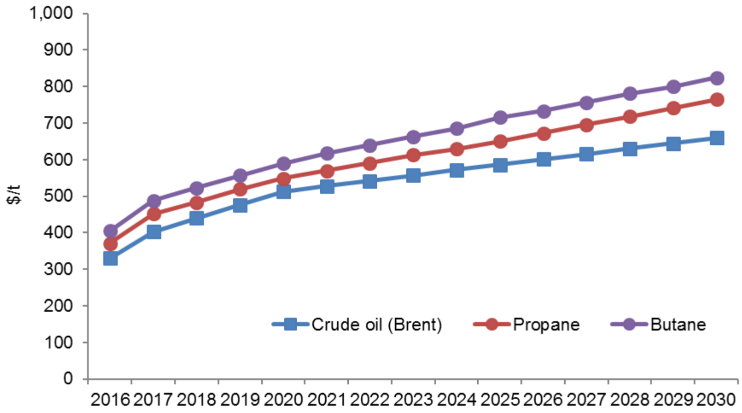
Source: U. S. Energy Information Administration, Annual Energy Outlook 2018

Figure 2.2-5 U.S. Oil and Gas Production Outlook

The second largest supplier, the Middle East will maintain its large influence on the world LPG market in coming decades. As associated production at oil and gas fields will remain as the major source of the supply in the region, expansion of refining capacity in the region will add another supply source. The Qatar plan of liquefaction capacity expansion from 77 million tonnes per annum (MTPA) to 110 MTPA will add an extra LPG supply from the expanded liquefaction plants. Production from Russia is also expected to rise as its natural gas production will increase in the future, too. Unlike other existing supply sources, production in Asia Pacific and Europe would not grow but decline.

(3) Price

LPG prices will remain linked to crude oil prices at least until 2030 although the degree of linkage may change. Because the production growth in the United States and the Middle East are significant and will exceed the demand growth, the overall market balance will be supply surplus until the mid-2020s.



Source: U. S. Energy Information Administration website

Figure 2.2-6 Price Forecast for Propane and Butane from The Middle East (FOB)

As the production growth in the United States will slow down beyond the mid-2020s, the demand growth will catch up with supply growth and the market will gradually be re-balanced. The price of LPG will therefore remain relatively cheap compared to crude oil price until the first half of the 2020s. This will be particularly the case with propane as its supply surplus will be larger than butane. Propane is more difficult to be absorbed in the petrochemical sector as opposed to butane, and thus its surplus will tend to persist. The relative price of LPG against crude oil price will improve in the latter half of the 2020s and beyond.

2.2.4 LPG Promotion in India

Around the turn of the century, many emerging countries embarked on campaigns for switching to cleaner cooking fuels. Notably, Brazil, Indonesia, China and India have successfully introduced LPG driving out dirty traditional fuels. Among them, this section reviews the history and present status of the LPG promotion policy in India.

1. Background of LPG Promotion in India

According to an IEA study “Energy Access Outlook 2017, India’s population without access to clean cooking were 753 million in 2000 or 71% of the population, and 834 million or 64% in 2015. The Census 2011 revealed that 86% of the households in rural areas and 23% of the households in urban areas were still using traditional biomass fuels for cooking such as firewood, crop residue and cow-dung cake. These fuels are not only inconvenient to use but create smoke, indoor pollution and affect the health of people, particularly women and children. Furthermore, women and girls bear the burden of collecting these fuels and are deprived of going to school.

2. LPG promotion

The Government of India (GOI, Federal Government) is promoting use of LPG as clean cooking fuel replacing traditional biomass fuel. As LPG is expensive, the GOI provides a subsidy for cooking purpose LPG used by household, or “Domestic LPG”.

In addition to the LPG subsidy, Ministry of Petroleum and Natural Gas (MoPNG) has created the “LPG schemes” to promote use of clean cooking fuel specifically designed for poor households as below;

a. Oil Sector Vision 2015 (2009)
   The Vision 2015 released in 2009 aimed to achieve 55 million new connections (to LPG) by 2015 to raise the population coverage of the clean cocking fuel from 50% to 75%. The total number of LPG customers should reach 160 million with most of the new connections being made in rural areas as urban areas are largely covered already. The Vision 2015 focused on the areas where LPG coverage was still low.

b. Rajiv Gandhi Gramin LPG Vitaran Yojana (RGGLV) (2009)
   To achieve the objective of the Vision 2015, a new scheme RGGLV was launched in 2009 to enhance setting up of small size LPG distribution agencies.

c. One-time Financial Assistance to BPL Category for new LPG Connection from RGGLV (2010)
   Grant of one-time financial assistance for Below Poverty Line (BPL) card holders was launched in 2010 for release of new LPG connections through RGGLVY. Under this scheme, costs of the Security Deposit and Pressure Regulator are met by the funds of the public sector oil marketing companies (OMCs) which was created for this purpose by the contributions from the Corporate Social Responsibility (CSR) Fund of six major oil companies.

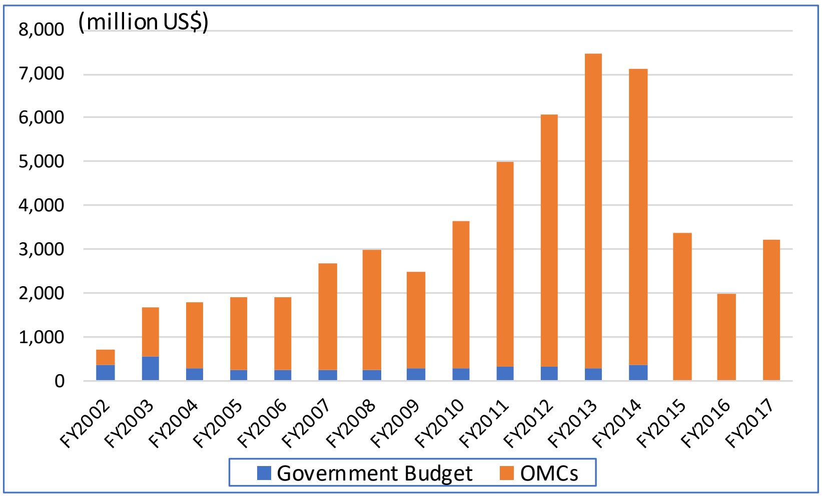
d. Pradhan Mantri Ujjwala Yojana (PMUY) (2016)
   In order to provide clean cooking fuel to poor households, especially in rural areas, the GOI launched PMUY in 2016 to provide 80 million deposit free LPG connections to women of BPL families.

3. Subsidy for LPG

The Government of India traditionally controlled oil product prices, while it has gradually reduced controlled items after the wake of First Oil Crisis. From 2002, only four oil products called “sensitive” petroleum products are controlled their prices, namely, Motor Gasoline, Diesel, Public Distribution System (PDS) Kerosene and Domestic LPG.

PDS Kerosene and Domestic LPG prices, both cooking fuels, are controlled officially. Motor Gasoline and Diesel prices were controlled through administrative directives to three national oil marketing companies (OMCs); Indian Oil (IOC), Bharat Petroleum (BPCL) and Hindustan Petroleum (HPCL). However, price control on motor gasoline and diesel has been already eliminated. At present, prices of PDS Kerosene and Domestic LPG are still controlled by the government with subsidies provided.

Subsidies for Domestic LPG were shared by the Government Budget and three national OMCs. Figure 2.2-7 shows evolution of the subsidy for Domestic LPG (14.2 kg Cylinder) in India. The subsidy scheme from the Government Budget was discontinued from April 2015. Since then, the Government has taken steps to rationalise subsidies and thus the amount of LPG subsidy is on a decreasing trend.



Source; Petroleum Planning & Analysis Cell and IEEJ estimation

Figure 2.2-7 Subsidy for Domestic LPG in India

4. Issues for LPG subsidy

As the LPG subsidy was not a targeted subsidy but a general subsidy, all consumers were able to enjoy the benefit. Consequently, most of the LPG subsidy was actually used to benefit the rich and the upper middle classes. According to the study "Report of The Expert Group to Advise on Pricing Methodology of Diesel, Domestic LPG and PDS Kerosene", only 0.07% of the Domestic LPG subsidies was going to the poorest class while 52.6% going to the richest class.

In 2010, a government committee recommended substantial reform of the sensitive petroleum products pricing policy including periodic increase of domestic LPG prices. The Union Budget sets out the government's intention to keep the total subsidies (not only for petroleum but also for fertilizer and food) below 2% of GDP in FY2012 and reducing it to below 1.75% of the GDP over the following three years.

In July 2012, MoPNG announced that the government was considering capping the number of subsidized LPG cylinders per household.

In June 2013, the Direct Benefit Transfer of LPG (DBTL) or PAHAL (Pratyaksh Hanstantrit Labh) scheme was launched. Under the scheme, cash subsidy is directly transferred to the bank account of the customer using his or her unique identification linked to the "Aadhaar" card after the purchase of LPG cylinder. DBTL has entered into Guinness Book of World Record being the world largest Direct Benefit Scheme. DBTL has helped identify the 'ghost' accounts, multiple accounts and inactive accounts. This has helped curb ill diversion of the subsidised LPG and normalise the LPG business.

The Government has further taken steps to rationalise the subsidy outgo by eliminating LPG consumers or his/ her spouse having taxable income above one million rupees (approximately 15 thousand US dollar) from availing the LPG subsidy.

In May 2015, MoPNG launched "GiveItUp" -Voluntarily giving up the LPG subsidy Campaign. According to MoPNG, more than 10 million consumers have given up their subsidy voluntarily.

While rationalising the general subsidies, the Government of India is promoting use of LPG providing several subsidies and incentives for poorest households, especially the PMUY scheme. However, it is reported that many users have reverted to traditional biomass fuels after buying the first LPG cylinder because LPG is expensive; 88% of the household discontinued use of LPG cited the high monthly expenditure. High price of LPG is still a barrier for lower income classes to continue using LPG.

2.3 Long Term Price Scenarios: Projection Before COVID-19

In conducting economic evaluation, the decisive factor above all is assumptions for the international oil and gas prices. In this sense, price scenario setting is an important factor that determines the life or death of a project.

Since we made an assessment on the world energy outlook in 2018, global energy market has been seriously affected by outbreak of the COVID-19 pandemic. In this section, we append the old projection just for reference. We will discuss the post-COVID-19 outlook in the next section.

2.3.1 Natural Gas Price Outlook

Since the summer of 2014, crude oil and natural gas prices have plunged from the historical high triggered by the Shale Revolution in the United States. The world crude oil price then recovered since 2017 largely due to sustained demand growth in the world and collective production cut by OPEC and non-OPEC countries. Because of this crude oil price recovery and remaining linkage of LNG price to crude oil price, the LNG price in Asia began to rise again although Henry Hub, a benchmark price in the United States, has remained low.

In the global gas market, Asia is expected to remain as the main source of demand growth. While European market may maintain its advantageous market conditions where it could secure import supplies from an extensive range of sources such as Russia, Africa, Middle East 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 and activated spot trading, in particular in the Pacific rim region. Based on the above analysis, natural gas price scenarios were set out as below.

Table 2.3-1 Natural Gas Price Scenarios (2018)

	Reference case			Low price case			Domestic gas	
	Japan LNG CIF $/MMbtu	Europe NBP $/MMbtu	US Henry Hub $/MMbtu	Japan LNG CIF $/MMbtu	Europe NBP $/MMbtu	US Henry Hub $/MMbtu	Starting price $4/MMbtu	$3/MMbtu
2017	8.1	5.8	3.0	8.1	5.8	3.0	4.0	3.0
2020	10.4	7.5	3.5	8.9	7.1	3.3	4.3	3.2
2030	10.5	8.2	4.2	9.9	7.8	3.8	5.3	4.0
2040	10.7	8.8	5.0	9.9	7.8	3.9	6.4	4.8
2050	10.8	8.9	5.2	9.9	7.9	4.0	7.8	5.9

Source: IEEJ Analysis

2.3.2 Crude Oil Price Outlook

Crude oil prices since 2014 was substantially affected by the Shale Revolution in the United States. After the oil price collapse to $35/Bbl in December 2014, oil price has gradually bounced back to above $70/Bbl in October 2018. Thanks to the recovery of crude oil price since 2017, its production has returned to a growing phase. In addition, the advanced hydrofracking technologies are being applied to conventional oil fields as well, which may lead to increased recovery.

On the demand side, oil consumption will maintain solid growth backed by the world economic growth, most of which is observed in non-OECD countries. While electric vehicles have caught a lot of attention, its fleet is not large enough as yet to cause a noticeable demand reduction effect. This Study expects that the world oil demand will continue to grow at least until 2040. The Study does not consider that world oil demand will peak and the price of oil will fall significantly due to the resulting lower demand.

In view of the above analysis the Study team adopted crude oil price scenario as below:

Table 2.3-2 Crude Oil Price Scenarios (NPS price assumtions to be updated)

	IEA 2018		IEA2018	EIA2018
	Ref $/bbl	Low $/bbl	NPS $/bbl	Ref $/bbl
2017	54	54.0	54.0	54.0
2020	80.0	75.0		70.0
2025	88.0	78.0		85.7
2030	95.0	80.0		92.8
2035	106.0	80.0		99.9
2040	115.0	80.0		106.1
2045	120.0	80.0		110.0
2050	125.0	80.0		113.6

Source: World Energy Outlook 2018, IEA; Annual Energy Outlook 2018, EIA; IEEJ Analysis

2.4 World of Post COVID-19

Since outbreak of the COVID-19 pandemic, oil and gas prices in the world spot market has shown violent up and down movements. These were caused by several transitory events such as technical troubles at newly starting up LNG plants and the cold winter in 2021 in addition to the demand shrinkage in 2Q 2020 caused by the pandemic and the demand bounce back in 3Q 2021 with ease of the pandemic.

The pandemic may cease some day in 2022 or latest in 2023. Then, the energy market will return to the normal trend. Oil and gas resources are ample thanks to the shale revolution. Fossil energy demand may be curved in accordance with enhanced efforts toward construction of a Net Zero society. In the long run, accordingly, energy prices will remain in a modest rising trend compared with former projections. We provide below our present review on the world LNG outlook and related issues, which is subject to substantial uncertainty pending our challenges during the winter of 2022 and beyond.

2.4.1 LNG Outlook

In 2020, the COVID-19 pandemic caused significant downturn of economic activities in the world and demand shock in the energy market. Thanks to the global vaccination promotion, economic activities are coming back in the summer 2021 bringing about rebalancing of the world LNG market.

Before the demand shock, world LNG market was expanding fast as several LNG projects began commercial deliveries. In addition, the rapid increase of LNG demand in Asia, especially China and India, also contributed to the robust trade in the market.

The booming world LNG trade has brought the industry into a new phase of flexibility, in particular, reflecting the request of new LNG importers for better volume flexibility; the traditional business model could no longer fully accommodate the needs of market participants. *New trading modes such as spot trading, short-term contract, arbitrage, equity lifting, and portfolio trading are spreading widely in the global LNG trade scenes.* In addition, the US LNG export, which is free from destination restriction, will bring about another layer of flexibility and liquidity into the market.

(1) Key factors in international LNG market

Noteworthy elements in the short to medium term world LNG market are summarised below. Topics are, on the consumer side, development of Asian market, on the supply side, new LNG supply from Qatar and the US after the robust supply increase in Australia and the US, and, on the technical side, rapid penetration of FSRUs (floating, storage and regasification unit).

a. China

China started importing LNG in 2006. In 2017, China imported 40 million tonnes (MT) of LNG, 47% higher than the previous year, and overtook Korea (39 MT) to become the world second largest LNG importer after Japan. In 2020, China imported 68.91 MT of LNG, accounted 19.44% of the world's LNG imports (356.1 MT) following Japan at 20.9%[9]. China is going to

[9] GIIGNL LNG Industry Annual Report 2021.

overtake Japan in 2021.

In 2020, LNG represented 28% of the country's total natural gas consumption, yet natural gas accounted for only 8.2% of the total primary energy consumption. Despite the increasing presence in the international market, LNG supplies only 2.3% of the country's total energy requirement. The Xi administration declared in October 2020 that China will aim to become a net-zero emission society by 2060. This implies potential of further big expansion of LNG import by China.

China was the first country hit by the COVID-19. Gas consumption in February reduced more than 9% year-on-year, with the industrial sector being hit hardest. Gas demand started to recover gradually from March with contribution of city gas for residential and commercial sectors and began to accelerate in August.

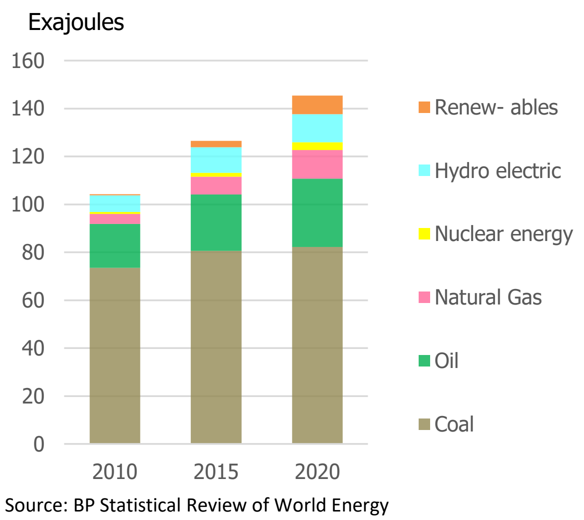
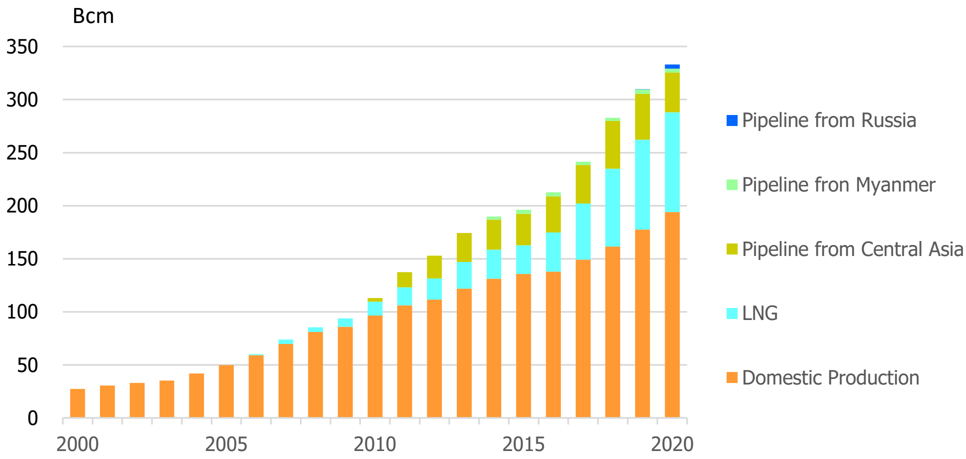


Figure 2.4-1 China's Total Primary Energy Consumption by Fuel Type

China launched coal-to-gas switching programme to combat air pollution in 2017, which caused abrupt increase in gas consumption incurring serious short supply. Learning from the severe experience, China established the China Oil & Gas Piping Network Corporation (PipeChina) in December 2019. It consolidated the pipeline, storage and LNG assets of Sinopec and PetroChina: this was one of the largest reforms in China's oil and gas industry. The company targets, in addition to secured gas supply by facility consolidation, to reduce gas prices, which will further boost gas demand in the country. While the largest gas users are industry and power generation, fuel switching in industry and city gas for residential and commercial sectors accounted for more than half of the total increase in gas consumption in 2020 while power sector gas use was controlled.



Sources: BP Statistical Review of the World Energy

Figure 2.4-2 Gas Supply Sources in China

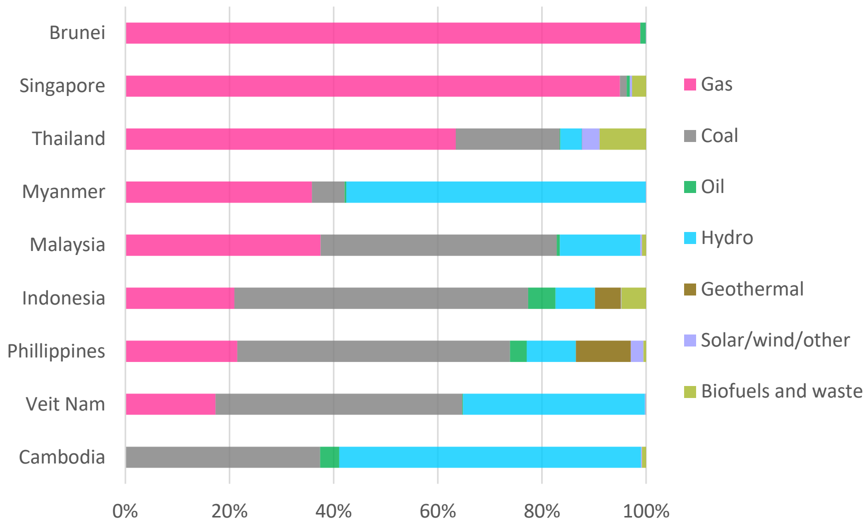
Domestic gas production and pipeline gas imports also affect China's LNG import. China holds the world largest shale gas resources (1,115 Tcf as unproved technically recoverable resources), equivalent to 15% of the global resources, though development condition is harsh. China's National Energy Administration sets shale gas development as a nationally strategic emerging industry and provides supporting subsidies and tax exemptions. Thus, all incremental gas production is expected to come from shale gas. In 2018, China's shale gas production reached 10.8 Bcm, 6.7% of domestic gas production. It is expected to further reach 65 Bcm between 2030-35[10].

China imports gas via pipeline from Turkmenistan, Kazakhstan, Uzbekistan, Myanmar and Russia. Imports from Russian east Siberia (Kovykta and Chayandin) started in December 2019 via the Power of Siberia pipeline (the eastern route) with a maximum capacity of 38 Bcm per year. Construction of the second Power of Siberia pipeline (western route) is being discussed between the two countries.

b. ASEAN

ASEAN (Association of Southeast Asian Nations) used to be a major LNG exporting region. However, after 2011, Thailand, Indonesia, Singapore and Malaysia have started importing LNG due to declining domestic gas production against increasing domestic energy demand. While ASEAN as a region is thought to remain as a net natural gas exporter until 2030, the region's LNG imports are expected to grow further.

10 Jiemian news, "中国页岩气高峰年产量或达 650 亿方，成为天然气产量增长主力［China's shale gas peaked 65 Bcm, becoming major gas production growth]," 2019, https://baijiahao.baidu.com/s?id=1643338954532135876&wfr=spider&for=pc.



Note: Energy balance data of Laos is not included in the IEA Energy Balances database

Source: Compiled by IEEJ based on data from Energy Balances of the World 2020 edition, IEA

Figure 2.4-3 Power Generation Mix of Major ASEAN Countries in 2018

The primary LNG consuming sectors in ASEAN are power generation and industry. As shown in Figure 2.4-3 below, natural gas is traditionally a major fuel for power generation in many ASEAN countries. With steady growth of electricity demand and public preference for a cleaner fuel, natural gas will remain as one of the preferred options for incremental power generation despite the depleting domestic production.

Like other regions in the world, gas consumption in ASEAN declined in 2020 due to the pandemic; dropping from 166.2 Bcm in 2019 to 155.7 Bcm in 2020, while LNG imports still grew from 20.7 Bcm to 23.0 Bcm in the same period[11].

Indonesia's gas demand declined 5.7% in 2020 as the key gas consuming sectors were cut back due to the pandemic. However, the gas demand is expected to recover as the government plans to replace 52 diesel power plants scattered in many islands with combined capacity of 3.69 GW of LNG driven generators. Indonesia aims to meet the target of gas utilization at 22% in 2025 and 24% in 2050[12].

Indonesia, once the world largest LNG supplier until the mid-2000s, became the second country in ASEAN to install an LNG receiving infrastructure in 2012. This is because of the geographical discrepancy of its demand centre and natural gas resources. Most of its natural gas demand exists in the western part of the country such as Sumatra or Java while its natural gas development is shifting to the eastern regions. Indonesia has three LNG liquefaction plants and five LNG receiving terminals in operation at the end of 2020. Two additional LNG plants are planned in the

[11] BP Statistical Review of World Energy

[12] LNG Producer-Consumer Conference 2020.

country. Abadi, an onshore project with capacity of 9.5 MTPA, will be put in operation in 2027.

In Singapore, fossil fuel imports are dominant among energy supply having no indigenous resources. Singapore started natural gas import by pipeline from Malaysia in 1992 and from Indonesia in 2001. With depletion of gas fields and increase of gas demand in both Indonesia and Malaysia, their gas exports gradually decreased. With this backdrop and strong intention to create an LNG trading hub, Singapore built its own LNG import terminal with a capacity of 6 MTPA in 2013[13]. Aiming to be the hub of Asian LNG market, Singapore has actively expanded its LNG facility for launching of LNG futures market and introduction of LNG bunkering. The terminal has since expanded twice to a total capacity of 11 MTPA[14]. Domestic gas demand recorded an uplift of 8% year-on-year in the first quarter in 2020, but, followed by sharp decline, remained at 0.1% growth in the whole year.

In Malaysia, geographical gap between natural gas resources and demand has forced the country to start LNG import just like Indonesia. The country's demand centres such as Kuala Lumpur exist in the west in Peninsula Malaysia, while the resource centre is located in the east Malaysia in Sarawak (Borneo Island): they are apart 1,000km across the South China Sea. The west Malaysia market used to be supplied via the PGU (Peninsula Gas Utilization) pipeline from the offshore peninsula gas fields. After the turn of the century, gas production started to decline while the demand increases. Malaysia is also a major LNG producer in the world, but the country had to find alternative supply source for the west Malaysia market. As pipeline connection from Sarawak to Peninsula Malaysia was difficult, Malaysia decided to build an LNG import terminal and started LNG import in 2013. As of the end of 2019, two LNG terminals with capacity of 7.3 MTPA are in operation at Melaka and Pengerang in Johor. While Malaysia imported 2.57 MT of LNG in 2020, import is expected to increase significantly as the Pengerang Integrated Petroleum Complex is going to build a refinery and petrochemical plants in phases.

In the Philippines, natural gas production is declining after peaking in 2014. The JICA/IEEJ team, in its Energy Master Plan Study in 2008, recommended the country to consider LNG import as the alternative gas supply source. The service contract of the Malampaya gas field will expire in 2024, and its production will stop soon after the expiration. The field's production supplies gas to three power plants in Batangas, in the suburbs of Manila, which supplies 30% of the total power demand in Luzon Island, the most populous island of the country. Decision was slow but, as the only realistic option is LNG, the country eventually decided to start LNG import in 2023. Similar requirements may arise in Myanmar in the near future, since their natural gas production is also maturing. It will be relatively easy in Myanmar to import LNG because the natural gas supply infrastructure has already been developed and in operation.

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13 EMA, "Energy Market Authority," 2017, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/EMA%20AR%202016_17.pdf.

14 SLNG, "Singapore LNG Corporation," 2018, https://www.slng.com.sg/website/binarystream_processor.aspx?T=0aZ8WbC4HVaz9he8XUSVtg%3d%3d&C=xY7y73A%2b0juirt16ZD912g%3d%3d&PK=DwkwGpfkLZ0%3d&K=D5566A&SC=1.

ASEAN is expected as a prospective market for virtual pipeline system with small scale LNG delivery network. In archipelagic countries such as Indonesia and the Philippines, many islands are traditionally using oil products for power generation. Replacing obsolete and inefficient oil-fired power plants with more efficient natural gas systems is desired. To enable this, it is necessary to create sufficient local demand, by aggregation and new generation, and clear the cost threshold together with optimization of logistics and preparation of affordable funds.

c. India and South Asia

South Asia is another driver for the world LNG demand growth. In India, fertilizer plants and oil refineries are the largest users, who are quite sensitive to price movement as alternative energy sources are readily available at their plants. LNG is also used for power generation. Given regulated electricity prices under the subsidisation policy, imported LNG is still not a preferred fuel even at lower prices prevailing last two years. Unlike China, India does not have pipeline imports. Plans for international pipeline connection from Turkmenistan and Iran are proposed and some has declared start of construction. However, these projects have not progressed due to serious security and geopolitical concerns; they would not materialise in the near future.

India's LNG demand is highly price-elastic and fluctuate violently reflecting movement of LNG price in the international market. Due to various price regulations, Indian buyers are intimidated to procure LNG under long term contract and/or when market price is high. Infrastructure is another challenge. Without pipeline network extended to interior states, LNG is mostly used in coastal areas near receiving terminals. Once pipeline network is developed to interior areas, together with energy pricing policy for stable use, substantial new demand will be open up.

Facing Covid-19, India implemented a strict lockdown between March and May. Gas consumption recorded a sharp decline in 2Q at 14% year-on-year. Demand gradually returned to the pre-Covid level by July. Gas consumption was 1.8% lower in the first eight months, and then recovered slightly to record a modest growth of 0.3% in 2020. Demand in city gas remains subdued, down by 30% year-on-year in August 2020. Due to the pandemic, commissioning of the Jaigarh FSRU terminal is delayed to Q1 2021 and the full operation of the Kochi-Mangalore transit pipeline to 2022.

LNG markets in other South Asian countries (Pakistan, Bangladesh, and Sri Lanka) have attracted considerable attention in the past few years. This region has a significant potential of LNG demand. Pakistan increased its LNG import to 10.6 million tonnes in 2020 from only 2.7 million tonnes in 2016, and its demand will continue to grow. Bangladesh started importing LNG in 2018 to address its severe energy supply shortage caused by stagnant domestic natural gas production and growing demand.

Besides the ever-increasing domestic energy demand, there are two common aspects for South Asian countries; firstly, their high dependence on oil products in the power sector as shown in Figure 2.4-4. Most of generation fuels in these countries are heavy fuel oil or diesel gas oil and their prices are linked to the international market. If environmental merit of LNG is duly considered, LNG, which price has significantly lowered in the international market in the last two years, will be recognized as economically beneficial compared to oil products.

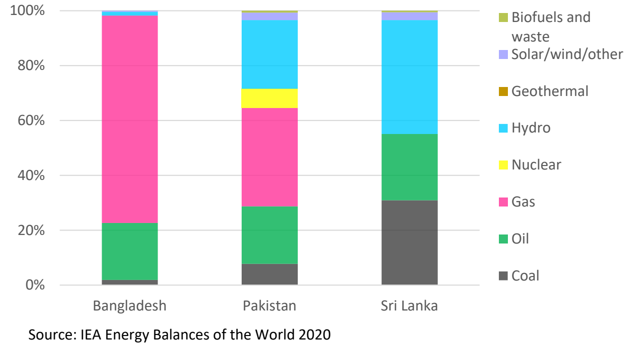


Figure 2.4-4 Power generation mix in Bangladesh, Pakistan and Sri Lanka in 2018

Secondly, the common aspect for Pakistan and Bangladesh is that both countries have indigenous natural gas production. Their future, however, is not very bright. In Pakistan, the natural gas production peaked in 2012 and is slowly declining afterward. In Bangladesh, while the domestic production is still growing, production is far short of the rapidly growing demand, and is uncertain how long it can continue to grow. Two countries need to find additional sources of natural gas supply. As they already have infrastructure for natural gas, introduction of LNG will be an easy option for them.

Similar to India, Bangladesh recorded a one-third drop of gas demand in April 2020 but has quickly recovered to around 95% of the pre-lockdown level by the end of June 2020. Gas demand remained at merely 1.9% decrease in 2020. On the other hand, LNG import rose by almost 24% in the first nine months, owing to completion of two gas pipelines that contributed to higher utilisation of the regasification capacity.

Pakistan reported a sharp 50% drop in daily gas consumption right after the Covid-19 restrictions enforced in April 2020. LNG imports fell 2% in Q1 and 29% Q2 year-on-year; recovery in Q3 was relatively slow; finally recorded -10.0% in 2020. Pakistan received its first spot LNG cargo in August after six months of absence in the spot market. As the government recently decided to facilitate third-party access to unused capacity at the country's two LNG import terminals, more purchase from the spot market is expected.

d. Qatari expansion

Because of its vast natural gas reserves and the world biggest liquefaction capacity, Qatar has played a key role in the world LNG market. In 2017 Qatar declared lift of the moratorium and expansion of the LNG capacity from the present 77 MTPA to 126 MTPA by 2027. Qatar insists on the environment sustainability in this plan. Significant lower CO_2 emissions is designed with

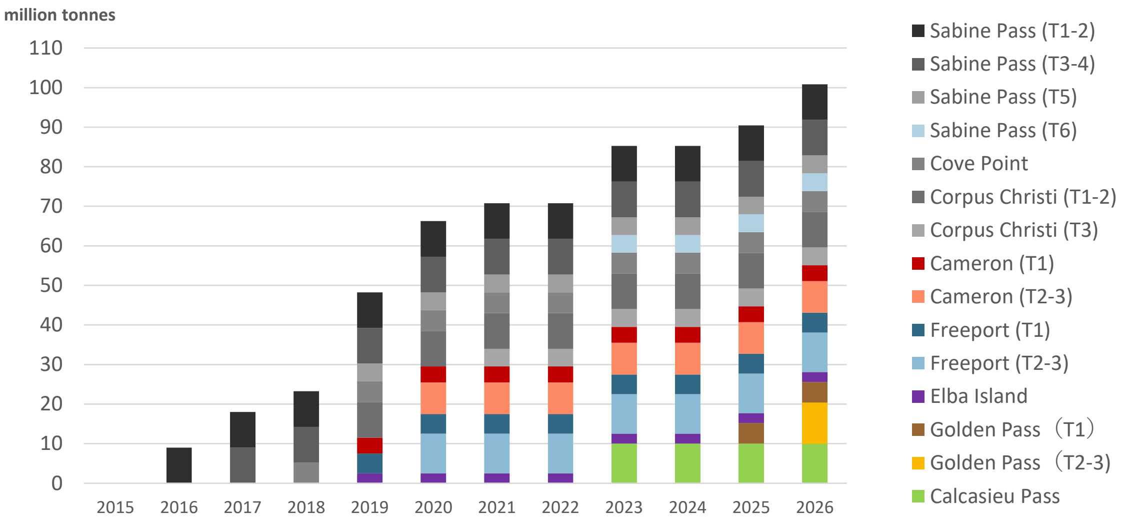
CCS (Carbon Capture and Sequestration). CNG will be used by vehicles for logistics during the construction phase. QP will build a world-class solar power plant to supply electricity for the LNG trains. The expansion is a package of debottlenecking of the existing trains and construction of new trains. In January 2021, Chiyoda Corporation of Japan announced award of these contracts amounting to one trillion yen (US$10 billion).

Qatari expansion plan may affect other new projects with relatively high-cost. Of course, the growing world LNG demand will require new and timely investments beyond the Qatari expansion. Unexpected delay of the Qatari expansion or other new projects might lead to an unexpected supply crunch in the 2020s. In view of its robust size, we need to keep eyes on development of the Qatari expansion project.

e. US LNG supply

The United States is one of the oldest LNG suppliers in the world. Its LNG export from Alaska started in 1969 greatly contributed to open up the LNG market in Japan. After a half century, the shale gas revolution in 2010 onwards has brought robust expansion of natural gas resource base reversing the anxiety on gas shortage to over-supply. Then, new LNG projects with giant capacity came up one after another. The country shipped the first LNG export from Lower 48 states in February 2016. In 2017, the United States exported more natural gas than imported for the first time since 1957.

In February 2021 the United States with liquefaction capacity of 69.1 MTPA was the third largest LNG exporter covering 10% of the global LNG exports. Supported by abundant supplies of shale gas and growing liquefaction capacity, the United States is expected to become the world largest LNG exporter by 2024, overtaking Australia and Qatar.



Source: Compiled by IEEJ based on publicly available information

Figure 2.4-5 The US LNG Production Outlook by Project, 2015-2026

One noteworthy aspect of the US LNG is its flexibility. Unlike the traditional LNG supply, it does not have a destination restriction and can be resold to other parties. This will enhance spot trading, may change the oil-linked pricing and create a more manageable benchmark. It may take time, but the US LNG will certainly bring about a structural change in the LNG market.

The demand shock by the Covid-19 pandemic has significantly impacted the US LNG production; more than 100 LNG cargoes were cancelled by Asian and European customers between June and August 2020. The 'second wave' of LNG projects were expected in the United States to be online by 2025, including mega-projects such as Driftwood LNG, Port Arthur LNG, Golden Pass, Calcasieu Pass LNG, Plaquemines LNG, Magnolia LNG, Jordan Cove LNG and Rio Grande LNG with combined capacity of 160 MTPA. Looking around the current global LNG market, however, it is uncertain whether these projects can secure funding and long-term supply deals to reach an FID. Only two projects - Golden Pass and Calcasieu Pass LNG - have reached the FID to date and started construction. Other liquefaction projects are mostly being delayed facing low LNG prices and uncertain economic growth.

f. Floating LNG Technologies

Floating liquefaction and regasification technologies are expanding in the LNG market. After Petronas launched the world first FLNG in 2018, there are 5 FLNG projects operating in Malaysia, Cameroon and Australia in February 2021. Two more are coming up; Coral South FLNG of Mozambique (3.4 MTPA) in 2022 and Tortue/Ahmeyim FLNG (2.5 MTPA) in Mauritania in 2023.

The largest benefit of the technology is that it does not need land and lengthy land preparation civil work to build. Construction work at site can be minimised, time saved and labour cost for facility construction also minimised. Drawbacks are its upfront concentration of capital expenditures (CAPEX), limitation on capacity expansion, and operational vulnerability to sea and weather conditions. Its operating expenses (OPEX) are higher than conventional onshore receiving terminals. Its receiving capacity cannot be expanded. In a country where LNG demand is expected to grow steadily, an onshore receiving terminal is desirable from long-term viewpoints. FSRUs are, however, often preferred in emerging countries as the CAPEX is significantly lower at roughly one half of an onshore facility and is introduced in a shorter period of time, usually within a year or so. This lower initial expenditure is a very appealing aspect for emerging importers with limited financial resources.

Issues will be solved partly by modification of existing LNG tankers, adoption of lease arrangement, and learning-by-doing. As of October 2020, 38 units of FSRUs are in operation and 56 projects are under construction or in the planning stage. FSRUs in fact have significantly lowered the hurdle of LNG introduction enabling a number of countries to access LNG.

Table 2.4-1 World FSRU/FSU Projects in Operation

Country	Project	Receiving capcity (1,000 tonnes per year)	Starting year
Jamaica	Montego Bay (FSU)	1,100	2016
	Old Harbour (FSRU)	3,600	2019
Bahrain	Bahrain LNG (FSU)	6,100	2020
Jordan	Aqaba LNG (FSRU)	3,800	2015
UAE	Jebel Ali (FSRU)	6,000	2015
	Ruwais (FSRU)	3,800	2016
Columbia	Cartagena (FSRU)	4,000	2016
Brazil	Guanabara Bay (FSRU)	1,840	2008
	Sergipe (FSRU)	5,500	2019
	Pecem (FSRU)	3,800	2009
	Bahia (FSRU)	6,000	2014
Egypt	Sumed (FSRU)	5,700	2015
Israel	Hadera Deepwater LNG (FSRU)	3,500	2013
Kuwait	Mina Al Ahmadi GasPort (FSRU)	5,800	2009
China	Tianjin offshore (FSRU)	3,210	2018
Malaysia	Sungai Udang (RGTSU), Melaka (FSU)	3,800	2013
	Pengerang (RGTP), Johor (FSU)	3,500	2017
Indonesia	Nusantara (FSRU)	3,000	2012
	Lampung LNG (FSRU)	2,900	2014
	Benoa (FSRU) (Small Scale)	4	2016
Pakistan	Port Qasim Karachi (FSRU)	4,800	2015
	Port Qasim GasPort (FSRU)	5,000	2017
Bangladesh	Moheshkhali (FSRU)	3,800	2018
	Summit LNG (FSRU)	3,500	2019
Lithuania	Klaipeda (FSRU)	2,900	2014
Russia	Kaliningrad (FSRU)	2,000	2019
UK	Teesside Trafigura (FSRU)	N,A.	2007
Italy	Toscana (FSRU)	2,800	2013
Turkey	Etki LNG (FSRU)	5,700	2016
	Dortyol (FSRU)	4,100	2018

Source: Compiled by IEEJ based on publicly available information

Table 2.4-2 FSRU/FSU Projects under Construction/Planning Stage

Country	Project	Receiving capcity (1,000 tonnes per year)	Starting year
Uruguay	GNL del Plata	2,500	planning stage
Brazil	Açu Port LNG	5,700	2020 (planning stage)
	Suape Golar Power (project title not identified)	N.A.	2021 (planning stage)
	Barcarena Vila do Conde	N.A.	2022 (planning stage)
Chile	Mejillones/Offshore	1,640	planning stage
	Penco Lirquén LNG	4,000	planning stage
	Bahia Chascos	N.A.	planning stage
Ecuador	Baja Alto	N.A.	planning stage
Ghana	project title not announced yet	N.A.	planning stage
	Quantum Powe	3,400	planning stage
	Tema	2,000	2020 (planning stage)
Cote d'Ivoire	Ivory Coast	3,000	2023 (planning stage)
Benin	Maria Gléta	N.A.	2021 (planning stage)
Kenya	Monbasa	1,300	planning stage
Senegal	project title not identified	N.A.	planning stage
Taiwan	Keelung Offshore	900	2025-2032 (planning stage)
China	Hong Kong/Offshore	N.A.	2021 (planning stage)
Thailand	project title not announced yet	5,000	2024 (planning stage)
Indonesia	West Java, Cilacap	1,200	planning stage
Australia	Crib Point LNG	6,000	2022 (planning stage)
	Port Kembla Gas Terminal	3,700	2022 (planning stage)
	Newcastle LNG	N.A.	2022 (planning stage)
	Geelong LNG	N.A.	planning stage
	Outer Harbor LNG	N.A.	2021 (planning stage)
The Philippines	Batangas	5,000	2022 (planning stage)
	Batangas	4,000	planning stage
	Cebu, project title not announced yet	N.A.	2022 (planning stage)
Viet Name	Thai Binh	200~500	2026-2030 (planning stage)
	Bac Lieu	N.A.	2024 (planning stage)
Pakistan	Port Qasim/Offshore (project title not announced yet)	4,500	planning stage
India	Jafrabad	5,000	2020 (planning stage)
	Kolkata	1,000	2020 (planning stage)
	East coast	5,000	2022 (planning stage)
	Karaikal	1,000~3,000	2021 (planning stage)
Sri Lanka	Kerawalapitiya	350	planning stage
	Kerawalapitiya	2,600~2,700	planning stage
	Hambantota(FSU)	1,000	2021 (planning stage)
Myanmar	Kanbauk	N.A.	2024 (planning stage)
	Mee Laung Gaing	N.A.	2024 (planning stage)
Latovia	Skulte LNG terminal(FRU)	N.A.	planning stage
Poland	Gdansk	3,700	2026 (planning stage)
Germany	Wilhelmshaven	7,300	2022 (planning stage)
UK	Port Meridian	5,000	2021 (planning stage)
Ireland	Port of Cork (project title not announced yet)	3,000	planning stage
Croatia	Krk island LNG	1,900	2021 (planning stage)
Albania	Eagle LNG	5,880	planning stage
Greece	Alexandroupolis	4,500	2023 (planning stage)
Ukraine	Yuzhnyi	N.A.	planning stage
Ukraine	First Gas	N.A.	planning stage
Turkey	Gulf of Saros (project title not announced yet)	N.A.	planning stage
El Salvador	Port of Acajutla (project title not announced yet)	N.A.	2021 (planning stage)
Cyprus	Vassilikos	740	2022 (planning stage)

Source: Compiled by IEEJ based on publicly available information

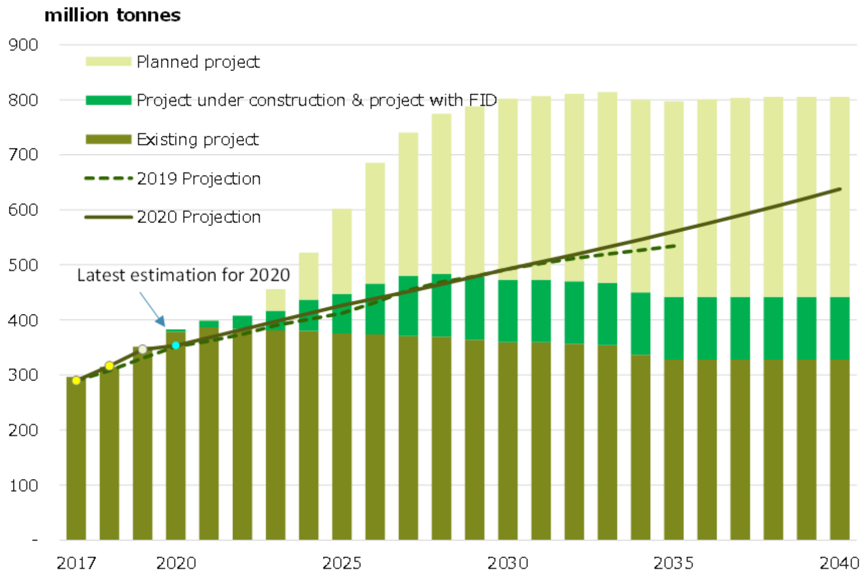
(2) Long-term LNG Demand and Supply Balance

Figure 2.4-6 shows the 2020 projection by IEEJ[15] on the long-term LNG demand and supply

[15] The Institute of Energy Economics, Japan, *IEEJ Outlook 2021*

outlook. LNG demand is only slightly affected by the pandemic in 2020 and 2021. Its long term trend remains strong as there are various positive factors to enhance natural gas consumption such as lower LNG price, growing concern on air quality and climate change. After slowdown 0.6% increase in 2020, the world LNG demand is soon returning to the long-term trend. Then, it will reach 493 million tonnes in 2030 and 638 million tonnes in 2040. Still, this projection needs further review watching how long the rampancy of Covid-19 would last after the 2021 winter.

LNG supply is estimated by adding on top of the existing liquefaction capacity, projects under construction, projects with a final investment decision (FID), and planned capacity that expects FID. The sum of these projects will peak in 2033 at 813 million tonnes and slightly decline thereafter to 806 million tonnes in 2040.



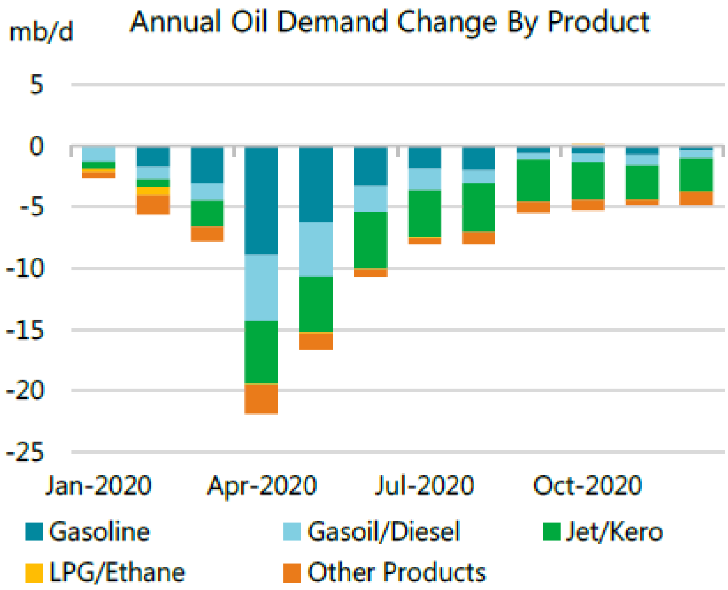
Source: IEEJ Analysis

Figure 2.4-6 Long-term LNG Demand and Supply Outlook: Post-Covid-19, 2017-2040

World liquefaction capacity was 452.9 MTPA at the end of 2020 while the volume of sanctioned liquefaction capacity in 2020 fell to its lowest since 2008, totalling only 3.25 MTPA due to COVID-19. Lockdowns and supply chain issues stagnated plant construction and companies delayed FIDs on potential liquefaction projects by several years due to the uncertain economic climate. Despite the delays and negative sentiment, the Calcasieu Pass LNG (10.0 MTPA) and Golden Pass LNG (15.6 MTPA), both under construction, are on track to start up on time. Calcasieu Pass LNG is scheduled to come online in 2022 while Golden Pass plans to have the first three trains commercially operational in 2024. It is uncertain how long COVID-19 will be prevalent. In the long run, however, the confirmed capacity exceeds the demand projection until 2029, which suggests surplus supply balance will continue for a medium term. After 2029 demand will overtake the confirmed capacity; market may become tight if the planned capacity would not be realised fully.

2.4.2 LPG Outlook

The world LPG demand is less affected by COVID-19 than other petroleum products' market. The demand for LPG was initially expected to experience a decline like other products after the outbreak of the virus. Surprisingly, however, its demand level maintained almost the same as the previous year. According to the analysis by International Energy Agency, the demand for LPG (including ethane) remained almost unchanged while the demand for other petroleum products, such as gasoline, diesel, and jet fuel, largely decreased due to the collapse of the global transport demand by lockdown (Figure 2.4-7).[16]



Source: International Energy Agency

Note: Figures beyond August 2020 are forecast

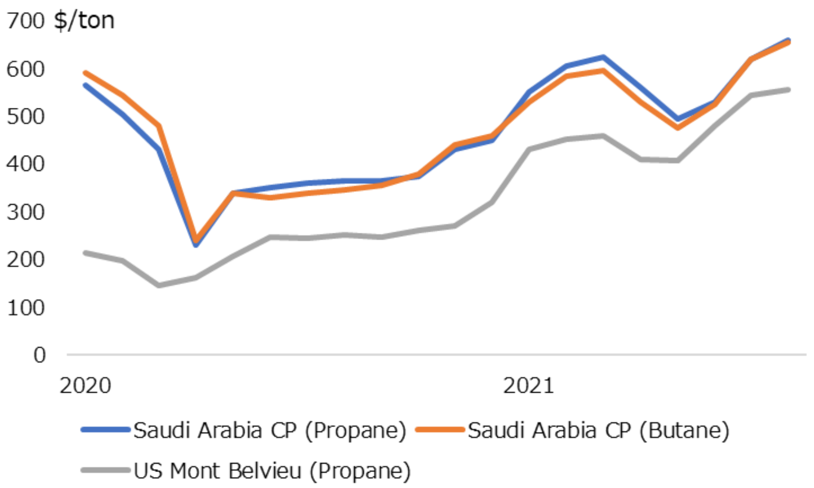
Figure 2.4-7 World Oil Demand Growth by Product

By region-wise, in OECD, LPG demand in the second quarter of 2020 was almost the same as the second quarter of 2019. LPG demand in OECD did not decrease like other petroleum products because i) the residential demand was strong as people stayed at home for a longer period during the lockdown, and ii) responses to COVID-19 created additional feedstock demand for petrochemical products such as packages for food, unwoven masks, and hygiene and medical products. In China, LPG demand experienced a decline in March 2020 compared to the same month 2019, but the demand recovered in April and has seen a growth since then reflecting its rapid economic recovery. Because two new propane dehydrogenation (PDH) plants came on stream in 2020, the demand for petrochemical sector gained another strength toward the end of 2020. India's LPG demand in the second quarter 2020 also exceeded the demand of previous year. This was largely because the Indian government provided free LPG cylinders for the residential

[16] The International Energy Agency, *Monthly Oil Market Report* (September 2020). (https://www.iea.org/reports/oil-market-report-september-2020)

sector as a policy package to manage the COVID-19 impacts. In general, the LPG demand in the world maintains a solid strength and performed best among the major petroleum products.

Despite the limited impacts to its demand, the price of LPG in Asia sharply dropped. The benchmark price in the U.S. market, loading price (FOB) at Mont Belvieu, had a limited drop and has maintained a similar level so far because the price level had been already low before the outbreak of COVID-19. But, Contract Price (CP) set by Saudi Arabia, a representative LPG price in Asia, declined almost by half from February to April 2020. The reason why the CP dropped despite the limited demand impact is because CP is calculated and set with reference to the crude oil market to maintain relative competitiveness of LPG against other petroleum products. The decline of crude oil price was reflected to the level of CP. Along with the recovery of crude oil price, however, CP turned to rise, and as of the spring of 2021, it recovered and surpassed the pre-COVID level as of 2019. From the summer of 2021, reflecting the tightened balance of international natural gas market, LPG price is rising.



Source: RIM Intelligence; U.S. Energy Information Administration, Japan LP Gas Association

Figure 2.4-8 World LPG Prices in 2020

In the long term, the demand of LPG will maintain the current strength and be back to the growth path assumed before the COVID-19 outbreak. Substitution of conventional biomass energy to LPG in the residential sector of emerging countries will not be affected by COVID-19 and continue as expected. COVID-19 may work positively to the residential LPG demand as people will stay at home for a longer period even after the virus is contained. LPG demand for petrochemical sector will also show a persistent growth. The recent growing awareness of plastic pollution problem may limit the demand growth to some extent, particularly in developed world, but developing alternative materials to the existing petrochemical products used for various final products is economically and technically challenging. Thus, LPG is likely to remain as a major feedstock of chemical products at least in developing world, and its demand outlook seems solid.

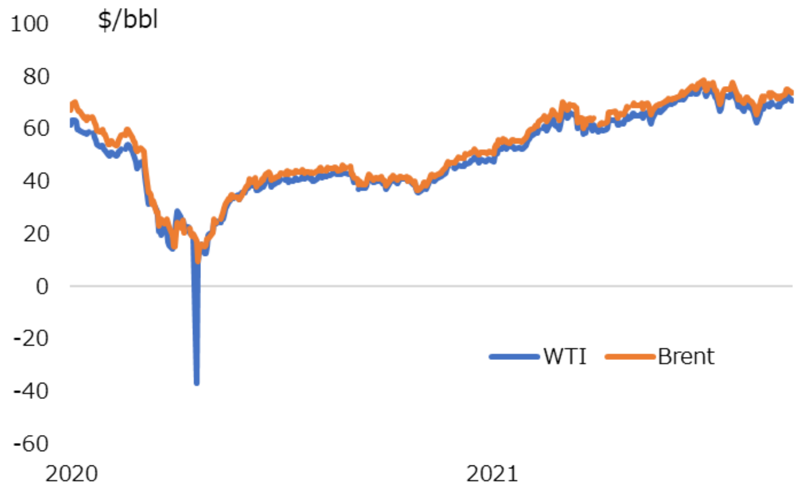
2.4.3 Oil and Gas Prices

Outbreak of COVID-19 in early 2020 brought substantial impacts on the global economy. The world oil and natural gas market were not immune to the impacts. Benchmark oil and gas prices sharply dropped due to the sudden decline of demand, but as of September 2021, the prices have more than recovered and running significantly higher than the pre-COVID level. The world is likely to overcome the COVID-19 upheaval by 2022 through expanded vaccination and recover the normal economic activities. This section observes the short-term impacts of COVID-19 to the world oil and natural gas prices and provides the long-term outlook of the world benchmark oil and natural gas prices in the post-COVID-19 world.

1) Observations of short-term impacts of COVID-19

Oil Prices

The impacts of COVID-19 appeared more evidently in the crude oil market than in the natural gas market. The price of Brent crude oil, a major benchmark price in the international crude oil market, collapsed from the level above $60/Bbl to below $20/Bbl from January to April 2020. The sudden fall of the price was partly attributed to the fact that Saudi Arabia and Russia could not make a deal for collective production cut and declared “price war” to maintain their own market shares in March 2020. This strife between the world major oil producers indeed occurred in the worst timing because the spread of COVID-19 was forcing major oil consuming countries in the world to impose lockdown or a similar restriction on movements of persons from exactly the same month as the price war began.



Source: U.S. Energy Information Administration

Figure 2.4-9 World Crude Oil Prices from January to September 2021

According to International Energy Agency, the world oil demand in the second quarter of 2020 declined by 16.4 million barrels per day year on year, which was unprecedently large and equivalent to the world’s demand growth in the past 16 years. In addition to the competitions among the oil producers, this record level of the demand decline caused the sudden fall of the international crude oil price. The futures price of West Texas Intermediate (WTI), another major benchmark price, even plunged below zero in April because majority of storage capacity of the delivery point of crude oil futures (Cushing in Oklahoma State) was fully leased out, and thus an entity who held the long position of the futures was forced to sell its crude oil with huge "payment" for an access fee to storage capacity in Cushing. The COVID-19 caused such unprecedented price behaviour in the world crude oil market.

After hitting the bottom in April 2020, the international crude prices began to recover. This was mainly because of the supply side adjustments, particularly by coordinated production cut among OPEC and non-OPEC producers ("OPEC plus"). While major oil producers launched the "price war" in March 2020, they soon realized that the magnitude of the ongoing demand decline was substantial, and they did not have a luxury to engage in futile conflict over the market share. OPEC plus swiftly made an agreement to jointly cut their production by 9.7 million barrels per day in April 2020. It is reported that the U.S. president Trump, who has political support bases in oil producing states in the United States, made phone calls to the leaders of major oil producing countries including the Russian president Vladimir Putin and the Saudi Arabian Crown Prince Muhammad bin Salman to make the collective production cut deal to raise the price level. In addition to the OPEC-plus joint production cuts, Norway, which was not a member of the collective production cut, voluntarily reduced its production by 250,000 barres per day. Furthermore, almost 2 million barrels per day production was forced to shut down in the United States in the second quarter of 2020 because of the low oil price. The sum of these production cut still fell short of the entire demand decline in the second quarter, but the reduced production greatly contributed to improve the market balance, restrain the inventory rising, and recover the price level above $40/Bbl in June 2020.

After the benchmark prices recovered $40/Bbl, they hovered around $40/Bbl as the OPEC-plus production cut helped to lower the global inventory.[17] The prices rose to around $50/Bbl from December backed by the loose monetary policy to stimulate the macro economy and to $60/Bbl in June 2021 with heightened expectation to earlier development and distribution of COVID-19 vaccines. The OPEC-plus keeping the tight production policy, it continued to rise and reached $80/Bbl in October 2021.

The demand recovery after the lifting of lockdown is leading to market rebalancing. The world oil demand, which declined by more than 16 million b/d in the second quarter 2020, is steadily moving back to the pre-COVID level, which narrowed the gap from the pre-COVID demand level to 5.8 million barrels per day. The demand impact of COVID-19 is thus likely to stay until 2022 at least, but with accelerated vaccination and the recovery of economic activities world oil demand is expected to restore the pre-COVID level by 2023.

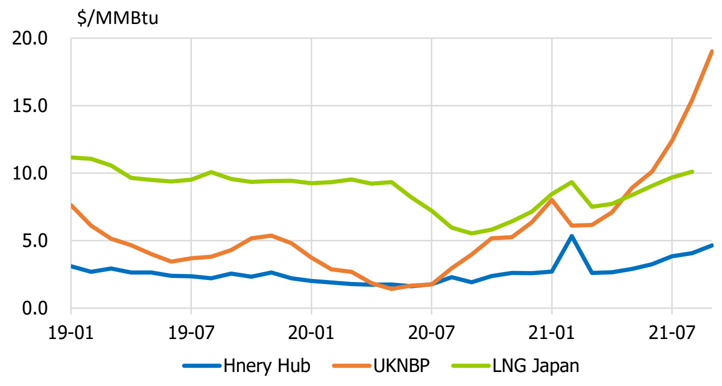
[17] Responding to the demand recovery, OPEC-plus increased the production by 2 million barrels per day from August 2020 and agreed to add another 500,000 barrels per day from January 2021.

Natural Gas Prices

Amid the rising demand for LNG reflecting ample supply and low hanging price, the world energy market was hit seriously by the Covid-19 pandemic leading to one of the largest demand shocks in the history. LNG spot price in the Asian market hit as low as $1.825/MMBtu in April 2020. Because of the pandemic, the global LNG demand was anticipated, around summer, to reduce 3-4% in 2020 while petroleum 8-10% reflecting the extreme reduction in aviation fuel. However, it remained strong and then cold wave hit the Northeast Asian market (Japan, Korea and China) which consumes more than a half of the world LNG. Eventually, the global LNG consumption recorded 0.6% increase in 2020.

LNG spot price turned upward since August 2020 and dashed up to $31/MMBtu in January 2021. This was caused by multiple events occurred simultaneously such as; shut down of nearly 20 plants elsewhere in Australia, the US, Qatar, Malaysia, Norway, Nigeria, etc. due to beginning stage troubles, hurricanes and other incidents; choke-up of LNG transport at the Panama Canal for increasing the GOM LNG supply for the Asian market; and finally, the cold wave. COVID-19 has prevented recovery operations at damaged plants. These elements are all temporary and the market is expected to calm down once they come back to normal. JKM spot price returned to $8.4/MMBtu early February 2021. The world natural gas market followed a similar path to the crude oil market although the magnitude of demand decline was moderate. While lockdown directly affected transportation demand of passengers and goods where oil is the primary energy source, natural gas demand for power generation and residential sector were less affected by lockdown.

Although relatively small compared to oil, demand of natural gas was affected by COVID-19 in absolute terms, particularly in the industrial and commercial sectors. While the demand and supply balance in the world natural gas market was lax before the outbreak of COVID-19, its impact on demand aggravated the already soft balance of the market. The U.S. and European benchmark prices further fell below $2/MMBtu from February and April, respectively (Figure 2-4. 10). Spot LNG price in Asia also fell to sub-$2 level in April, well below the cost of supply.



Source: IEEJ, U.S. Energy Information Administration; Trade Statistics of Japan

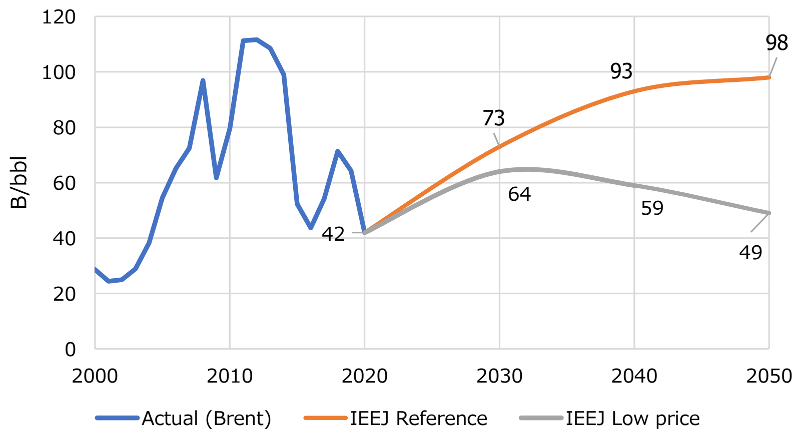
Figure 2.4-10 World Natural Gas Prices from January 2020

In the summer of 2021, however, European gas price began to pick up in anticipation of the reduced stock after the cold winter, and reached historically high level in the autumn. LNG spot price is following this, though not shown in the graph. It exceeded $15/MMBtu in July and, with strong hurricanes attacking the Gulf of Mexico, running around $25/MMBtu in September 2021. JLC (Japan LNG CIF), which comprises mainly long-term contracts, also exceeded $10/MMBtu in August. This phenomenon may be transitory and may cease by the spring of 2022, as Russian Nord Stream 2 is scheduled to start soon in Europe and additional LNG plants are coming up in the US.

2) Modified price outlook in the long-term

As the history shows, the world will one day overcome the damage of virus, and the world economy will regain the previous strength. Energy demand will recover the growing trend. On the other hand, movement toward a Net Zero society is gaining momentum worldwide, which will significantly enhance introduction of renewable energy and promotion of efficiency. Despite the significant fluctuation in the short term, the world oil and gas price will go back to a milder trend in the long run.

In the crude oil market, as the world oil demand will grow, the supply source will shift to more high-cost reserves. The shale oil production in the United States, for instance, will move from a limited number of low-cost "sweet spots" to a more high-cost reservoirs in the long run. Furthermore, reflecting the size of proven reserves, the supply share of OPEC-plus is expected to increase in the long run. As long as the collaboration of OPEC-plus is maintained, the price level will be managed by the oil producers' alliance and will not persistently remain at a low level. Based on these assessments, the long-term crude oil price forecast is provided as shown in Figure 2.4-11. The price will increase to above $70/Bbl as of 2030 and then continue rising slowly to almost $100/Bbl as of 2050.



Source: IEEJ Analysis

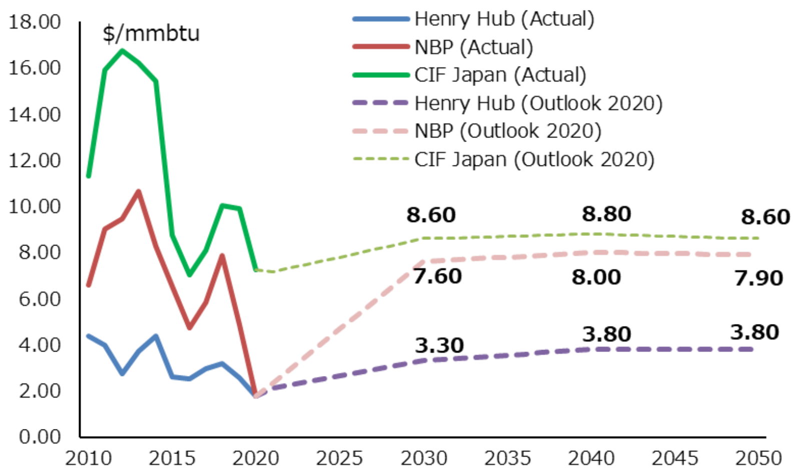
Figure 2.4-11 Price Outlook of Crude Oil

On the other hand, in a case where technology development and switching to renewables progress fast, oil demand and its price would peak in the 2030s and start to decline then. A low price scenario is also developed as shown in the same figure. However, we should note that 3/4 of oil supply needs to come from new fields in 2050.[18] We should carefully investigate if new oil supply could be available at a price lower than $50/Bbl in future.

Table 2.4-3 Price Outlook of Crude Oil

	IEEJ2021 Ref $/bbl	Low $/bbl	IEA2021 STEPS $/bbl	EIA2021 Ref $/bbl
2020	42	42	42	42
2030	73	64	77	73
2040	93	59	-	87
2050	98	49	88	95

Demand of natural gas will also recover as the world overcome the impact of COVID-19. Advantages of natural gas, such as lower carbon footprint, abundant geological resources, convenience of use, are not affected by the COVID-19. Amid the concerted voices for a Net Zero Society, however, demand growth may become milder than previously expected despite that natural gas is likely to be chosen as a preferred energy source. On the other hand, gas resources are abundant thanks to the shale revolution. Natural gas prices may stay at a milder level than projected before. In the gas import markets in Asia and Europe, natural gas prices may remain below $10/MMBtu through 2050 as shown in Figure 2.4-12.



Source: IEEJ Analysis

Figure 2.4-12 Price Outlook of Natural Gas

By region-wise, the natural gas price in the United States will remain the lowest in the world supported by abundant resources and well-developed infrastructure. The low price prevailed until recently around $2/MMBtu will not last long because of the increasing finding and development

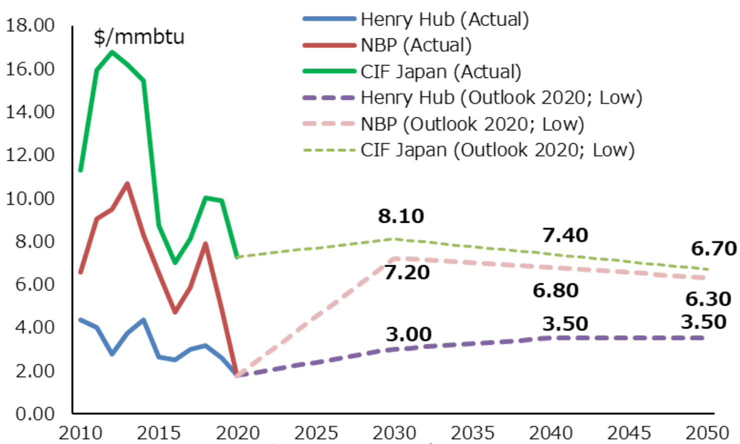
[18] IEA World Energy Outlook 2020.

costs and the demand growth including the export by LNG. The Asian LNG price (CIF Japan), on the other hand, will see a moderate recovery toward 2030 backed by the demand growth in emerging Asian demand. Thanks to the enhanced market liquidity and activated arbitrage trading in the international LNG market, the price differentials among the regions will narrow down.

Besides this "reference," or the most likely case in the post-COVID world, another scenario of "lower price" case is worth considering given the latest developments of energy and environmental issues. In this price scenario, the recent trend to seek for a low-carbon society may accelerate the energy transition from traditional hydrocarbon energy to zero-emission energy such as renewable, nuclear, and hydrogen. Under such scenario, the oil demand will be significantly reduced by the penetration of next-generation vehicles such as electric vehicles (EV), plug-in hybrid vehicle (PHV), and fuel cell vehicle (FCV). Biofuel may also be more extensively utilized for jet fuel or shipping fuels and replace the conventional crude oil-based fuels. In this scenario, crude oil price may rise until 2030 but turn out to decline afterwards because the world oil demand will begin to slow down and eventually decline as shown in Figure 2.4-11.

This low-price scenario is also applicable to the natural gas market. Although natural gas used to be praised for its cleanness among fossil fuels, it has increasingly become regarded as one of fossil fuels and an energy source to be substituted by zero-carbon energy, particularly in Europe. A scenario where natural gas is also aggressively phased out is not so an unrealistic scenario, and, under such case, its price level will also decline over the long term after peaking in 2030 as shown in Figure 2.4-13.

In this projection, however, since cheaper gas supplied to the Asian market will be mostly LNG, natural gas wellhead price needs to be below \$3.00/MMBtu. To find new resources at this price range will be a challenging task.



Source: IEEJ Analysis

Figure 2.4-13 Price Outlook of Natural Gas (Lower price case)

In the above scenario setting, price projection is revised downward significantly compared with the previous one even for the Reference Case. The present boiling market will calm down after the winter thanks to the ample supply base. However, currents in the market may change triggered by any event.

Against these development in demand as explained above, the supply side may lag to respond. According to the International Energy Agency, the global investments in the oil and gas sector is expected to decrease by a third in 2020.[19] This large investment cuts affects natural gas and LNG production capacity investments. The reduced investments will be translated into lower supply capacity in the future through delay or cancellation of capacity expansions, and, after the world natural gas demand is back to growth path, such reduced capacity expansion may cause tight market balance in the medium to long term. Furthermore, the recent global trend among the international financial community to take cautious approach to finance fossil fuel projects (even those of the least carbon intensive natural gas), may also limit the upstream investments in the supply capacity. These developments may work as upward pressures on the price level.

In addition, south-east Asian countries are facing a critical issue on their power development plan. Facing the global chorus on carbon emissions reduction, Japan and Korea have cancelled cooperative funding for construction of coal-fired power station one after another in the past three years. China followed this in 2021. Thus, almost 50 coal power plant plans in the south and south-east Asia are stranded while electricity demand is on a strong growth path. Their power plans fell in chaos. Solution to this will be natural gas since renewables could not be the backbone of the power supply system unless enormous investment is made in hydro power, battery, power transfer network, etc. This may push up LNG price in the medium term.

At least, we should note that the above price projection is for real term prices; nominal prices are projected to rise substantially. Considering market vulnerability, we should design our system flexible and resilient to price fluctuations.

2.4.4 Petroleum Products Price Outlook

For economic evaluation of GTL, DME and MTG projects, prices of petroleum products as their 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, Singapore spot market prices for the past 10 years (Japan CIF price for LPG) are used as a large and reliable statistics. From the average figures for each product, the value ratios of petroleum products over the crude oil mix are calculated on a calorific basis as shown in Table 2.4-4. On top of the 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.

[19] International Energy Agency, "The Covid-19 crisis is causing the biggest fall in global energy investment in history," 27 May 2020. (https://www.iea.org/news/the-covid-19-crisis-is-causing-the-biggest-fall-in-global-energy-investment-in-history)

Table 2.4-4 Value Ratio of Petroleum Products

	Brent $/MMBtu	Gasoline $/MMBtu	Naphtha $/MMBtu	Kerosene $/MMBtu	Gas Oil $/MMBtu	LPG $/MMBtu
Hstorical Price	14.2	18.6	15.6	17.3	17.2	15.0
Import Price	100%	131%	110%	122%	121%	106%
Wholesale Price, +20%		157%	132%	146%	145%	127%
Wholesale Price, +20%		22.3	18.7	20.8	20.6	18.0

Source: IEEJ analysis

Chapter 3 Natural Gas Utilisation in Japan

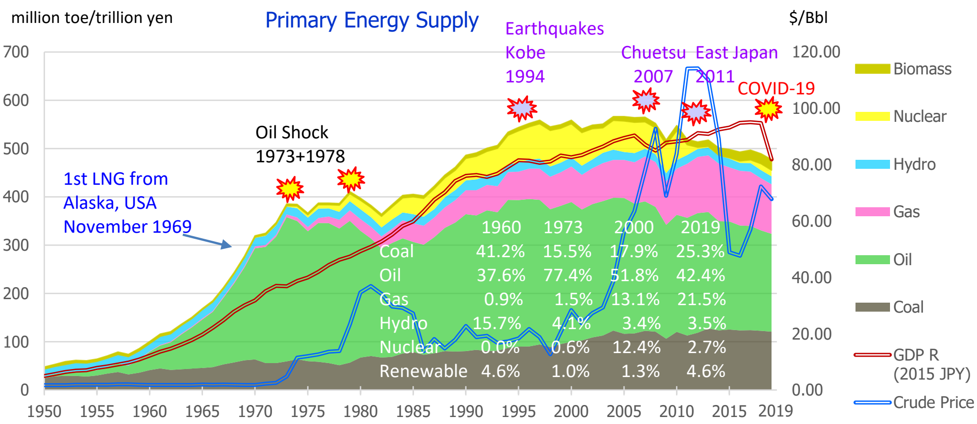
Japan started gasification of its economy from a very low level in the middle of the 20th century, and developed gas use quite rapidly to become the world largest LNG importing country. To understand issues and solutions relating to gasification, this chapter reviews the history of gasification, gas utilization pattern, gas supply system and gas promotion policies adopted in Japan.

3.1 Japan's History of Natural Gas Utilisation

During Japan's post-war reconstruction stage, sky-rocketing energy consumption caused serious air pollution at various industrial development centres. Concerns on the air-quality heightened and strict regulations were enforced in particular to recover the azure sky for the 1964 Tokyo Olympic Games. This became the strong motives for Japanese to pursue gasification policy developing LNG import, which was further accelerated to enhance the national energy security facing the oil crises in the 1970s.

Since then, LNG projects targeting at Japan were developed elsewhere in Southeast Asia, Australia and the Middle East aggressively under the initiative of Japanese consortia, and thus Japan soon became the world's largest LNG importer.

In the 1990s, the global movement for market liberalization landed Japan and the regulated city gas market was gradually developed into industrial and commercial sectors. After the turn of the century, LNG become more competitive in the market as oil price jumped up reflecting rapid demand growth in emerging countries such as China and India. During such booming time, two giant earthquakes hit Japan and the Japanese nuclear power stations were completely shut down after the second one in 2011. In the latter occasion LNG played an indispensable role in supplementing the power shortage. Against these backdrops, natural gas supplied over 20% of Japan's primary energy demand in 2019.



Source: IEEJ "EDMC Handbook of Japan's & World Energy & Economic Statistics 2021 "

Figure 3.1-1 Primary Energy Supply in Japan

3.1.1 Introduction of LNG

Natural gas resources are scarce in Japan. Hence a tiny amount of natural gas was used in the early time only in the vicinity of the gas producing provinces. In big cities like Tokyo and Osaka, coal based city gas was supplied mainly for households as fuel for cooking and hot water supply, while firewood and charcoal were used in smaller cities and rural areas. Coal and oil were burnt at factories and buildings as industrial fuel or fuel for space heating.

Large scale natural gas supply in the form of LNG was proposed by American companies as early as 1957. Tokyo Gas decided to introduce it as city gas companies were suffering from fatal accidents caused by toxic coal gas and difficulties to develop gas delivery capacity in congested urban areas with low heat value gas. However, the demand size in hand by the company was too small to justify the proposed 1.3 MTPA LNG project. Tokyo Gas therefore asked Tokyo Electric to join in the project.

During the post war reconstruction period, Japanese fuel consumption was skyrocketing with development of heavy and energy intensive industries. Cheap and abundantly available high sulphur heavy fuel oils became popular. They were produced from the Middle East crude oils as international oil majors were promoting the development of newly discovered giant oil fields in that region. This resulted in serious deterioration of air quality in the urban areas and industrial centres, threatening development of industrial complex that drove high economic growth. To cope with the situation, the Japanese government started regulating fuel sulphur content. In Tokyo, municipal governments were eager to restore the blue sky for the 1964 Olympic Games and set out a very strict regulation that forced new power station use fuels with sulphur content of less than 0.1%. Facing fast increasing power demand, Tokyo Electric decided to accept the request of Tokyo Gas to facilitate their new power plant plan with sulphur free LNG. Thus, the first LNG project for Japan started its supply from Alaska in November 1969.

Figure 3.1-2 First LNG for Japan

3.1.2 The Oil Crisis to Promote Alternative Energy

When the Japanese oil industry was busy coping with air pollution by introducing low sulphur crude oils or desulfurization plants, another incident happened: the oil crisis. On October 17, 1973, upon outbreak of the 6th Middle East war, OPEC declared an oil embargo reducing oil supply to hostile countries. People rushed for panic buying. In Japan, daily goods mostly disappeared from the shelf of shops. In the United States, people made long queues at gasoline stations to refill their only half-empty fuel tanks.

Under the circumstance, Henry Kissinger, then the US State Secretary, proposed to form an international alliance of the OECD countries. The International Energy Agency (IEA) was created in 1974 as an arm of the OECD to collectively work for secure and stable oil supply at reasonable prices. The IEA members agreed to implement:

a) Promotion of oil stockpiling; and
b) Ban on construction of oil-burning power stations

In concert with this, the Japanese government hammered out a series of energy policies to promote:

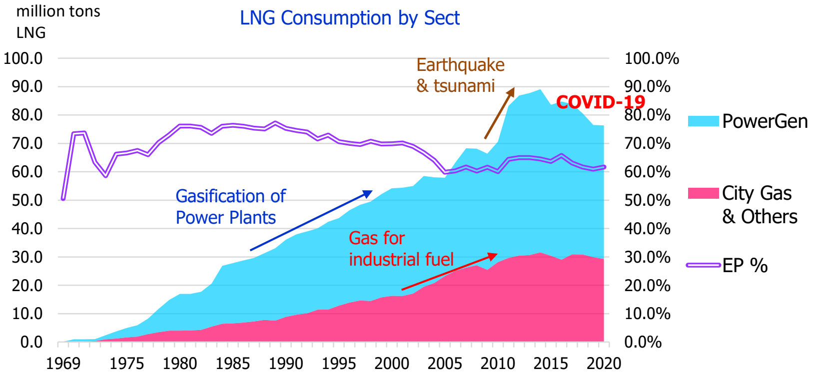
a) Oil stockpiling;
b) Alternative energies: LNG, Nuclear, NRE;
c) Energy conservation and efficiency;
d) Energy technologies development;
   - Sunshine Project to develop technology on new energies;
   - Moonlight Project to develop technology on energy efficiency;

Source: Petroleum Association of Japan

Figure 3.1-3 Oil Stockpiling

The Japanese government prompted switching to alternative fuels in every sector with strong policies and regulations; natural gas and nuclear became the energies of choice. Improvement of energy efficiency was also enhanced leading to changes in the industrial structure from heavy to light along with adoption of energy efficiency technology and equipment. While the total energy consumption almost stopped increasing, LNG import increased at a high speed.

In the course of the rapid gasification, the principle of gas and power collaboration was maintained, where gas thermal power plants provided the anchor demand to justify the creation of new LNG projects. In addition to the gas companies in big cities, smaller city gas companies also switched to LNG. They were facing problems with aging coal gas plants and decided to adopt LNG rather than to rebuild plants with old-fashioned technology. In switching to LNG, they needed generous big partners who could offer the platform for stable LNG import. During the early period, the business scope of city gas companies was strictly regulated to pursue the responsibility as public utility. Accordingly, the share of LNG use for power generation remained just above 70% during the 20th century.



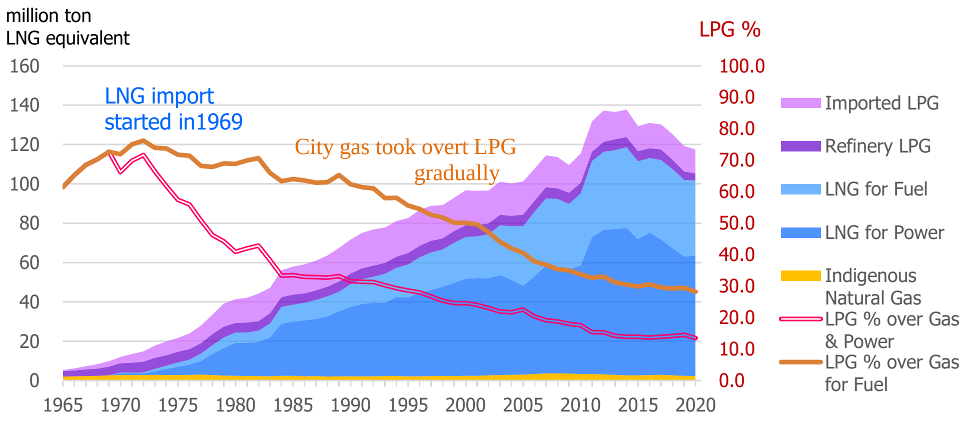
Source: IEEJ "EDMC Handbook of Japan's & World Energy & Economic Statistics 2021 "

Figure 3.1-4 Natural Gas Consumption by Sector in Japan

Liberalisation and marketisation became the world trend toward the end of the century and the Japanese city gas regulation was gradually liberalised as city gas industry established strong foundations with expanding business. Gas supply for large users at negotiated prices was allowed in 1990 and this policy was later expanded to cover smaller consumers as well. Share of city gas in the LNG consumption increased steadily. Then, the breakout of the Great East Japan Earthquake and the tsunami knocked down the entire Japanese nuclear power generation in 2011, and the LNG use for power generation jumped up to supplement power shortage.

3.1.3 Gasification with LNG

In Japan, nationwide gasification started with introduction of LPG in 1950. In the non-gas producing provinces, cooking fuel was switched from firewood and charcoal to kerosene at first, but when LPG was introduced after a short while, people rushed to the odourless gas. LPG penetrated quickly replacing traditional fuels. When import of LNG started, LNG overtook the wave from LPG.



Source: IEEJ "EDMC Handbook of Japan's & World Energy & Economic Statistics 2021 "

Figure 3.1-5 Gas Fuel Supply in Japan

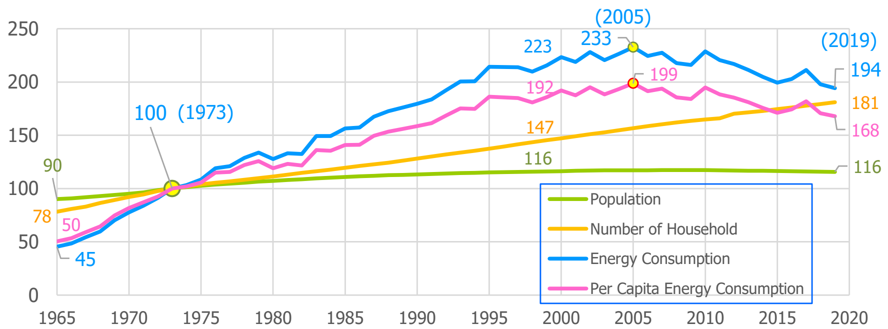
Although the apparent LPG share in the gas fuel dropped quickly, this was due to the substantial increase of LNG supply for power generation. Developing city gas supply system needs huge investments and long lead time, and thus the ratio of LPG to the total gas fuel supply remained at around 70% for almost 20 years. It started to decline in the middle of the 1990s as LNG based city gas system with small scale facilities, a new concept as explained in Section 3.3, was increasingly developed in smaller local cities in Japan.

From the above experience, we learn that:

a) People prefer gas fuel for cooking to smoky and harmful traditional fuels;
b) LPG is a quicker option in the early stage;
c) City gas systems require large upfront investments and certain period of time to develop;
d) Once city gas network is completed, hands-free city gas is preferred to other fuels;
e) Large scale gas consumption at factories and for power generation is selected according to socio-economic requirement.

3.2 Trend of Energy Consumption in Japanese Residential Sector

Energy consumption in residential sector of Japan rapidly grew up until the first oil crisis in 1973. After the second oil crisis in 1979, the growth in energy consumption in the residential sector slowed down but still continued until early 1990s reflecting proliferation of nuclear or single households and continued modernisation of life style that pushed up purchase of electric appliances. From 1995 to 2010, energy consumption in the residential sector remained generally at the same level. After 2010, it started to decline despite the increase in the number of households reflecting energy conservation efforts such as dissemination of energy efficient home appliances, improved insulation of houses, and heightened awareness to energy saving. Energy consumption in 2019 dropped by 17% compared with the peak demand recorded in 2005.

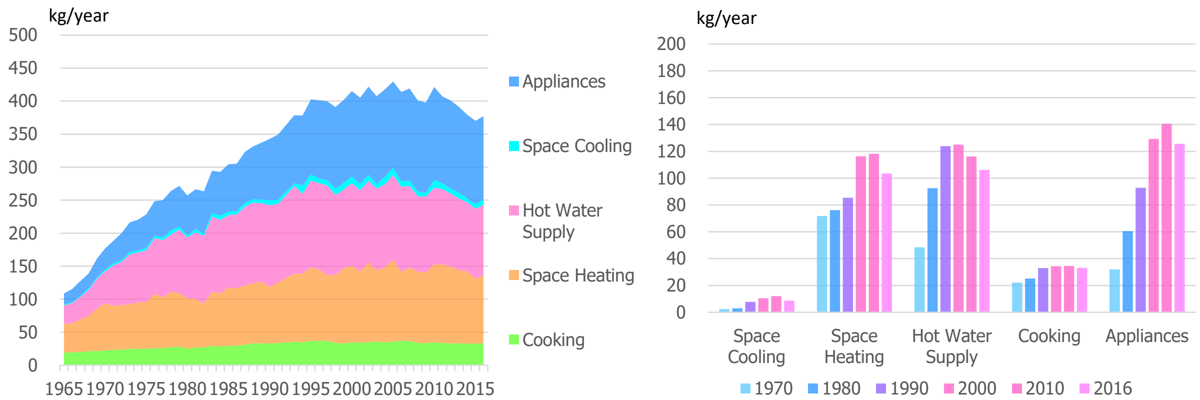


Source: IEEJ "EDMC Handbook of Japan's & World Energy & Economic Statistics 2021 "

Figure 3.2-1 Trend of Energy Consumption, Population, and Household in Japan

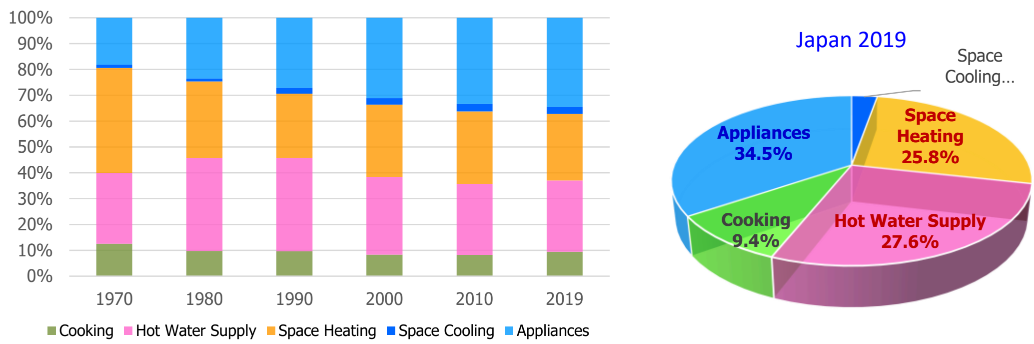
Energy consumption per capita in 1965 was about 109 kg oil equivalent; more than 30% of it was used each for hot water supply and space heating. With modernization of life style and increase in the number of households, energy consumption per capita steadily increased and reached its peak of 430 kg oil equivalent in 2005. Subsequently, it gradually decreased to 363 kg oil equivalent in 2019 reflecting energy conservation efforts.

Of these usages, energy consumption for home appliances grew by purchase of new electric appliances and its share increased from 20% in 1965 to 34.5% in 2019. Energy consumption in space cooling increased through dissemination of air conditioners, although its growth rate was relatively slow due to significant improvement in energy efficiency. Energy consumption for space heating steadily increased until mid-2000s. Afterwards it started to decrease reflecting improved insulation of houses and its share declined to 25.8% in 2019. Energy consumption for use in hot water supply rapidly increased up to the mid-1990s. After that, its share gradually decreased from 34.6% in 1990 to 27.6% in 2019 reflecting development of high efficiency water heater applying heat pump technology and increased awareness of energy conservation. On the other hand, energy consumption for cooking has remained almost at the same level, and thus its share decreased from 16% in 1965 to 9.4% in 2019 as the total energy consumption increased more than three-fold during the period.



Source: IEEJ "EDMC Handbook of Japan's & World Energy & Economic Statistics 2021"

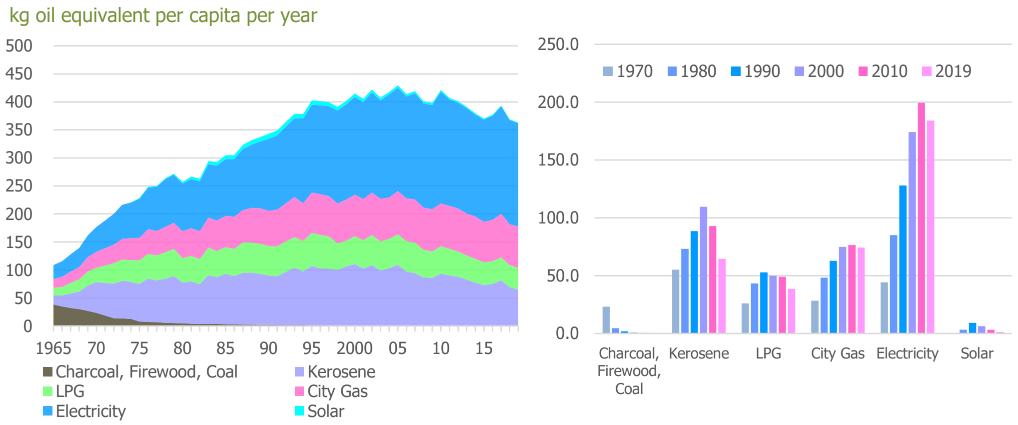
Figure 3.2-2 Trend of Energy Consumption in Residential Sector by Use



Source: IEEJ "EDMC Handbook of Japan's & World Energy & Economic Statistics 2021"

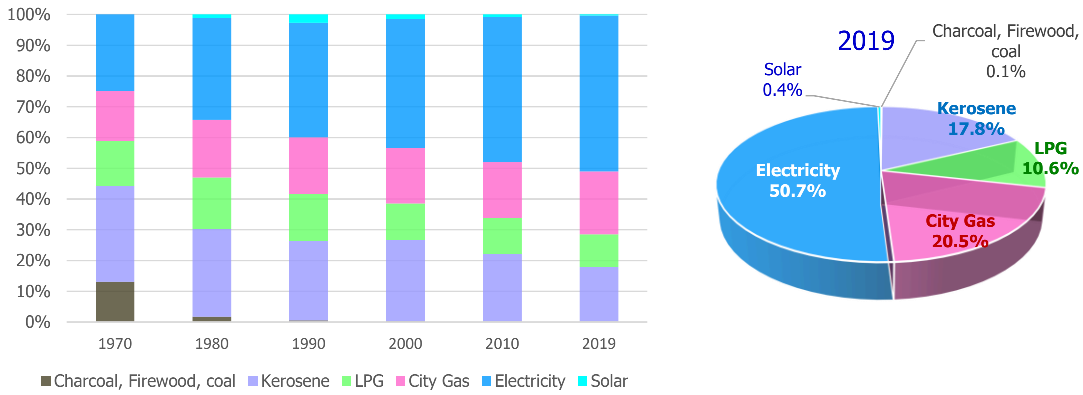
Figure 3.2-3 Share of Energy Consumption in Residential Sector by Use

In 1965, more than one-third of the total energy consumption in the residential sector was charcoal, firewood and coal. By 1975, these fuels rapidly decreased being replaced by kerosene, gas (LPG and city gas) and electricity as shown in Figure 3.2-4. After 1975, these three energies continued gradual increase; electricity demand increased fastest among them reflecting increase of lighting equipment and electric appliances, dissemination of heat pump type hot water supplier, air conditioner, etc. In 2019, the share of electricity reached 50.7% of the total residential demand.



Source: IEEJ "EDMC Handbook of Japan's & World Energy & Economic Statistics 2021 "

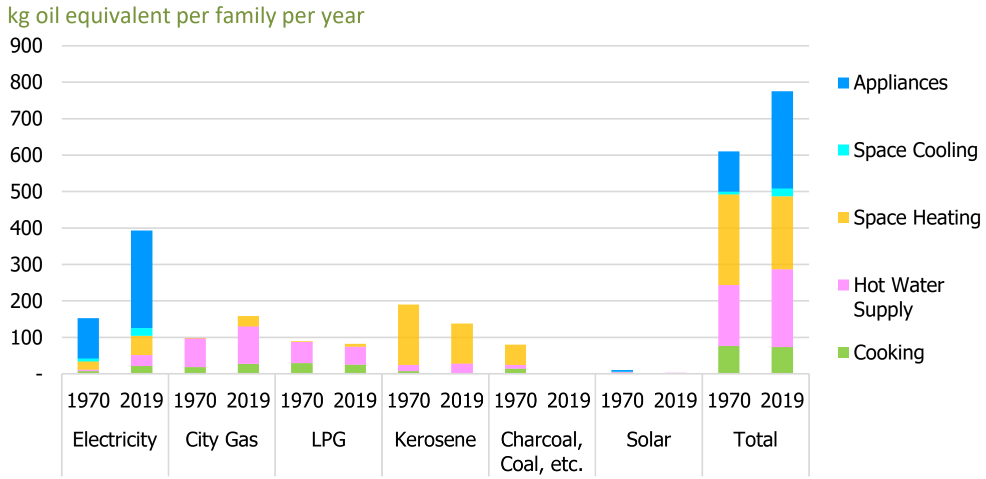
Figure 3.2-4 Trend of Energy Consumption in Residential Sector by Source



Source: IEEJ "EDMC Handbook of Japan's & World Energy & Economic Statistics 2021 "

Figure 3.2-5 Share of Energy Consumption in Residential Sector by Source

Kerosene consumption mainly for space heating steadily increased until mid-2000s. After then, however, it started to decline due to decreasing use of kerosene stoves and fuel switching to electricity and gas. In 2019, the share of kerosene was 17.8% of the total energy consumption. Gas demand has increased in line with increasing demand for hot water supply. In particular, city gas demand increased reflecting fuel switching from LPG and kerosene to city gas and the dissemination of hot water supply systems such as floor heating and heater/dryer for bathroom despite the fact that demand for hot water supply itself decreased since 1990. However, gas demand started to decrease after 2005 because of shifting from gas to electricity on one hand due to promotion of all-electrified home system and improving energy efficiency of gas-burning appliances on the other. The share of gas demand still keeps the 30% level even though the gas demand is decreasing in absolute quantity. Among gas fuels, city gas overtook LPG in the 1990s and now holds a larger share than that of LPG. Solar hot water systems that were popularized after the oil crises in the 1970s are on a declining trend since 1990.

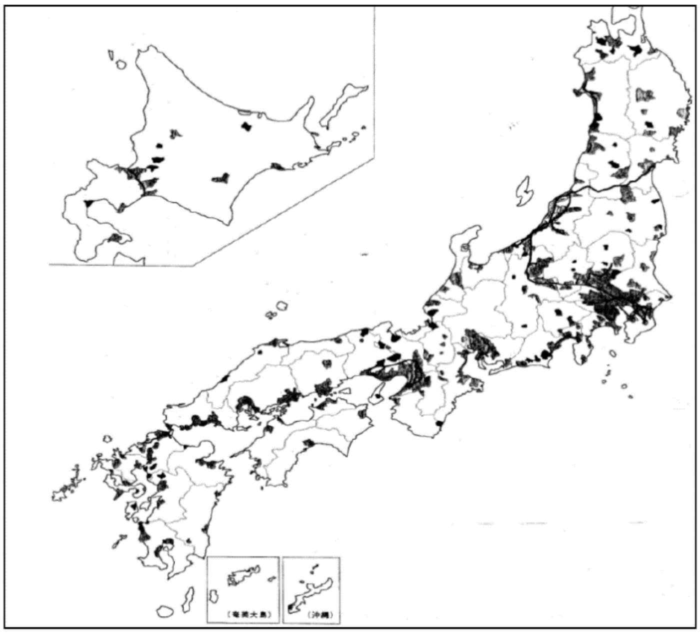


Source: IEEJ "EDMC Handbook of Japan's & World Energy & Economic Statistics 2021 "

Figure 3.2-6 Energy Consumption in Residential Sector by Use and by Source

3.3 Natural Gas Supply System

In Japan, 70% of the total land is covered by mountains and forests while habitable areas are less than 30%. Among them, city gas supply area covered by piped gas delivery system is only 5.5% as illustrated in Figure 3.3-1. There are 203 city gas companies in Japan and more than 80% of city gas is served by top 10 gas companies as shown in Table 3.3-1. In other words, there are many small local city gas compnaies serving small and confined markets. Most of them now use LNG as feedstock. Small scale LNG transport and delivery systems have been developed nationwide in the past two decades to accommodate requirements of distributed smaller users.



Source: METI

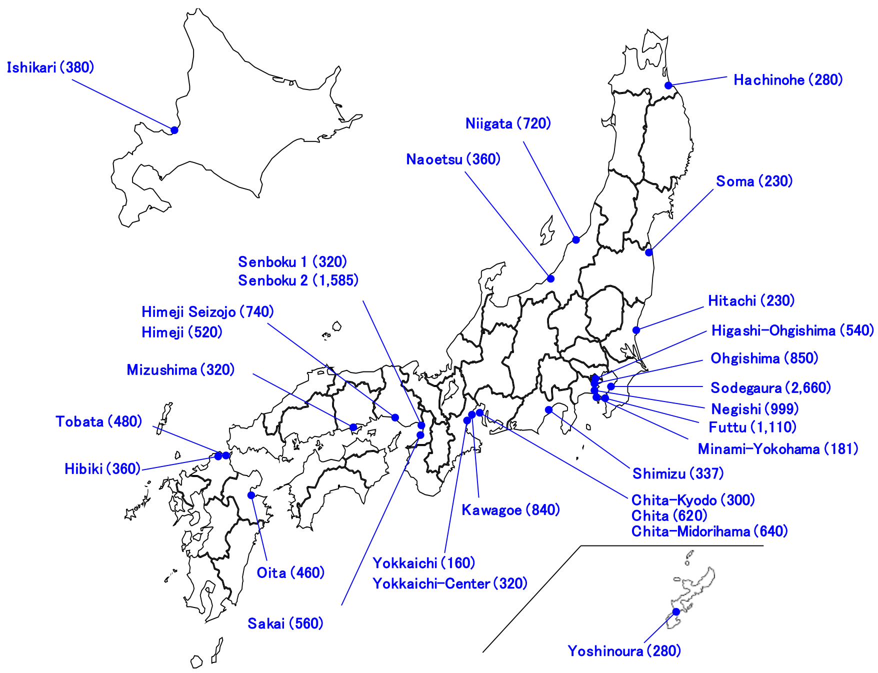
Figure 3.3-1 City Gas Supply Areas in Japan

Table 3.3-1 Top 10 Gas Companies in Japan (as of March 2017)

	Company	Sales Volume (1,000 MJ)	No. of Customer	No. of Employee
1	Tokyo Gas	595,532,460	11,388,965	8,135
2	Osaka Gas	367,797,649	7,310,123	5,680
3	Toho Gas	164,946,095	2,410,543	2,886
4	Otaki Gas	36,796,273	169,034	266
5	Shizuoka Gas	36,379,415	318,296	645
6	Saibu Gas	35,586,452	1,098,398	1,325
7	Keiyo Gas	30,169,523	917,680	849
8	Hokkaido Gas	24,832,890	565,947	914
9	Hiroshima Gas	19,697,850	409,881	637
10	Hokuriku Gas	14,226,414	371,770	412
	Others	232,084,410	5,176,363	10,340
	Total	1,558,049,431	30,137,000	32,089

Source: Japan Gas Association

Most of natural gas supplied as above is LNG imported from abroad. To develop and promote gas use, LNG receiving terminals are built in different areas scattered all over Japan; presently there are 29 LNG receiving terminals as shown in Figure 3.3-2. The total tank capacity amounts to 17.38 million kl. In Japan, seasonal changes in temperature and the difference between summer and winter are significant. For this reason LNG tanks are prepared to accommodate high natural gas demand in the heating season.



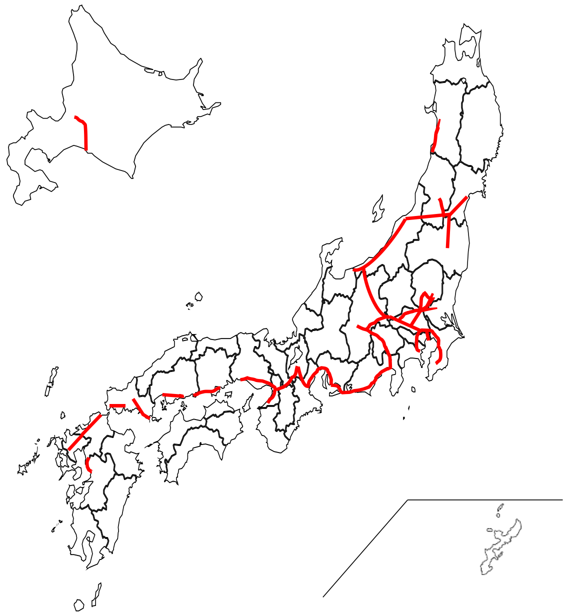
Note: ( ): Storage capacity, 1,000 kl

Source: JICA Study Team

Figure 3.3-2 LNG Receiving Terminal in Japan

3.3.1 Natural Gas Pipeline

Construction of natural gas transmission pipelines started in late 1950's and the total length of existing transmission pipelines is 5,000 km, of which 2,600 km was built before 2000. Moreover, there are plans to construct additional 350 km of pipelines by 2026. Figure 3.3-3 shows the existing natural gas pipelines in Japan. Diameters of pipes typically range from 50 to 750 mm where 600 mm is popular.



Source: JICA Study Team

Figure 3.3-3 Natural Gas Pipeline in Japan

3.3.2 LNG Tank Truck

Other than pipeline, LNG tank trucks serve as a major land transport system from LNG receiving terminals to remote areas. LNG is loaded onto LNG tank trucks at an LNG shipping station and transported to secondary LNG receiving terminals called "Satellites" at remote locations near the consuming area.

Source: Hokkaido Gas

Figure 3.3-4 14 ton LNG Tank Truck

The capacity of tank trucks ranges from 7 to 15.7 tonnes, where the popular tank capacity is 14 tonnes. The maximum size of LNG tank truck is regulated at 15.7 tonnes under the Road Traffic Law of Japan. It takes about one hour each to load and unload at both terminals. Except for time required in loading and unloading, the distance that one driver can transport LNG is a maximum of 200 km, assuming driver's standard daily working hours at 8-9 hours. The length and width of an LNG tank truck is 17 m and 2.5 m, respectively. Width of road needs to be 7.5 m or more considering their turning radius. Generally speaking, costs of the truck head and cryogenic tank trailers are JPY15 million and JPY55 million (JPY110/US$) respectively. Truck fuel is diesel and its mileage is 2-3 km per litre.

Table 3.3-2 Specifications of LNG Tank Truck

Capacity (ton)	Length (m)	Width (m)	Height (m)	Required Road Width (m)
8.0	11.95	2.49	3.28	6.4
10.5	15.48	2.49	3.44	7.0
14.8	16.48	2.49	3.38	7.5
15.1	16.98	2.49	3.38	7.7
15.7	16.98	2.49	3.39	7.8

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

3.3.3 Rail Freight Containers

In addition to tank trucks, railway containers are available as an option to transport LNG on land. In this mode of transport, special tank containers are used as shown in Figure 3.3-5. The LNG containers are at first carried by flat trailers from the base LNG terminal to the departing railway station, then transferred by rail to the destination station, and again carried by trailers to the satellite terminal near the demand sites (see Figure 3.3-6). If branch rail lines are available both at the base LNG terminal and the satellite facility, LNG can be transported solely by rail throughout the route. However, as construction of such service line is costly in Japan, LNG containers are transported by combination of trailers and railway. For lifting and unloading of LNG containers on and off flat wagons at the freight stations, a heavy lift vehicle called "Top Lifter" is used as shown in Figure 3.3-7.

In Japan, railway transport of LNG using a 30-ft standard freight container was developed and commercialized in 2000 by Japan Petroleum Exploration Company (JAPEX). In this system, two 30-ft containers are loaded on a flat wagon. Subsequently in 2002, a system using 40-ft containers with LNG loading capacity of 13.5 tonnes was developed. Based on a 20-wagon freight train, this system can haul up to 540 tonnes of LNG per trip. Another merit of the system is that the CO_2 emission of railway system is lower than that of tank truck system.

Source: JAPEX

Figure 3.3-5 LNG Tank Containers

Source: JAPEX (http://www.japex.co.jp/english/business/japan/lng.html)

Figure 3.3-6 Rail Transportation of LNG

Source: JAPEX

Figure 3.3-7 Container handling with a Top Lifter

3.3.4 Coastal Vessel

For local markets where demand size is insufficient to justify a direct LNG import from abroad, another option is available to transport the imported LNG from the main receiving terminal to a secondary terminal using smaller coastal tankers. While large LNG tankers with capacities ranging 130,000 - 260,000 cubic meters (maximum loadable LNG: 59.000 - 122,000 tonnes) are used for ocean transport of LNG, specially built coastal tankers are used in Japan since 2003 to transfer LNG to smaller secondary terminals. Presently there are six of these in operation with loading capacity in the range of 2,500 - 3,500 cubic meters (1,100-1,600 tonnes). Loading time for a 2,500 m^3 vessel is about 10 hours and unloading time is about 9 hours. Fuel used by the tanker is bunker oil and the fuel consumption is about 23 litres per mile. Figure 3.3-8 shows M/S NORTH PIONEER used by Hokkaido Gas.

Source: Hokkaido Gas

Figure 3.3-8 Coastal Vessel NORTH PIONEER

Table 3.3-3 Outline of NORTH PIONEER

Length	89.2 m
Width	15.3 m
Draught	4.3 m
Gross tonnage	3,056 ton
Tank capacity	2,500m^3 (1,000 ton)
Speed	13.3 knot

Source: Hokkaido Gas

3.3.5 LNG Satellite Terminal

Figure 3.3-9 shows a general layout of an LNG satellite terminal. Such facilities have been developed to enable use of LNG in remote locations where pipelines are not commercially accessible. An LNG satellite terminal is a secondary LNG receiving terminal, and a number of these can be laid out around a main terminal like satellites that orbit around a planet, hence the appellation. An LNG satellite terminal consists of LNG tank(s) and vaporizer(s), with a land requirement of about 400m^2 which is considerably smaller than the main LNG terminal. While a secondary terminal for receiving coastal tankers has similar equipment and functions, but is larger in size and requires berthing facility to receive coastal tankers.

Table 3.3-4 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 7,600 households (160 m^3/household-year) in Japan for one year. The required number of LNG tanks and vaporizers depends on the gas demand.

Construction cost of an LNG satellite facility depends on capacity and the site condition. Table

3.3-5 shows examples of specifications and cost of two facilities constructed in the past by Japanese engineering companies. Table 3.3-6 shows an example of specifications and construction costs of secondary terminal for coastal vessel.

Source: Tokyo Gas Engineering（http://www.tge.co.jp/service/lng/satellite/）

Figure 3.3-9 LNG Satellite Terminal Layout

Table 3.3-4 Specification of LNG Satellite Facilities

			Case 1	Case 2	Case 3	Case 4	Case 5
LNG supply capacity		ton/year	8,000	6,000	4,000	2,000	1,000
LNG tank	Capacity	kl/unit	125	100	70	70	40
	Number	Unit	4	3	2	1	1
LNG vaporizer	Capacity	ton/hour	1.2	1.0	0.5	0.3	0.2
	Number	Unit	2	2	2	2	2
Gas pressure		MPa	0.2-0.15				
Stock amount		day	5.0	5.4	3.8	3.8	4.3
Required land space		m x m	24x17	24x17	18x22	16x16	15x15

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

Table 3.3-5 Specification and Construction Cost of LNG Satellite Facilities

			A company	B company
Year of the completion			2002	2015
LNG tank	Capacity	kl/unit	150	100
	Number	Unit	2	2
LNG vaporizer	Capacity	ton/hour	1.0	6.0
	Number	Unit	5	3
Construction cost		1,000US$	4,240	10,833

Source: JICA Study Team

Table 3.3-6 Specification and Construction Cost of Secondary Terminal for Coastal Vessel

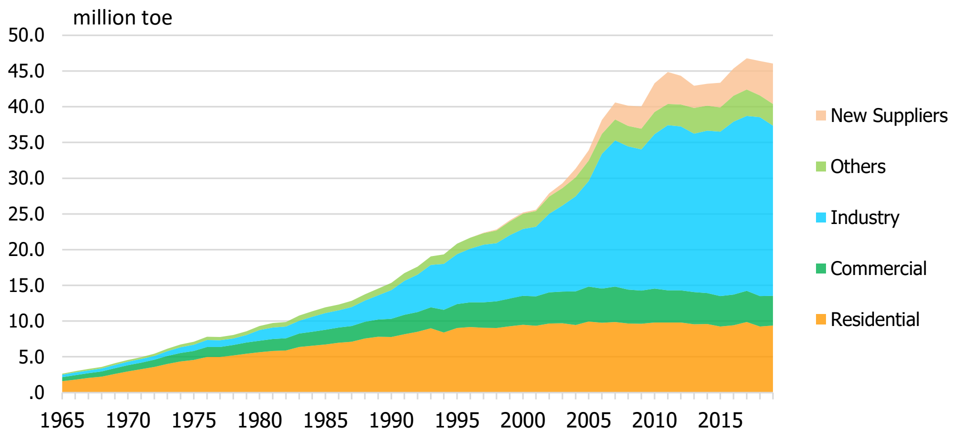
			A company	B company
Year of the completion			2005	2015
LNG tank	Capacity	kl/unit	5,000	12,000
	Number	Unit	1	1
LNG vaporizer	Capacity	ton/hour	2.0	2.85
	Number	Unit	3	6
Construction cost		Million US$	91	50

Source: JICA Study Team

3.4 Natural Gas Promotion Policies in Japan

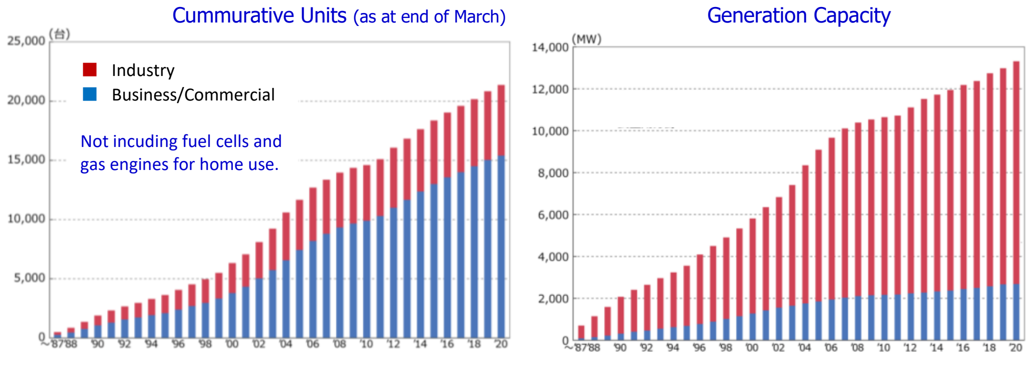
The amount of city gas sales in Japan has grown at a much higher rate than the final energy consumption. In particular, city gas sales for the industrial sector increased rapidly after 1980 boosted by concerns on CO_2 emissions reduction, advantages in easy handling, and tax incentives for accelerated depreciation. As the strong enabler, the Japanese government provided several subsidies for fuel switching to natural gas, introduction of cogeneration system, and so on. As a result of these strategically designed policies, city gas sale for the industrial sector was significantly accelerated since mid-1990s. Thanks to these tax incentives and subsidies, the share of city gas in the industrial sector fuel use expanded rapidly from 16% in 1980 to 58% in 2019 as shown in Table 3.4-1.

Among the usages, cogeneration systems in the industrial sector consume a huge amount of city gas. It is believed that the introduction of cogeneration system in the industrial sector has greatly contributed to the expansion of gas consumption in Japan. In addition, Japan started a subsidy system for fuel cell system for household in 2009. After aggregate sale of home fuel cell systems exceeded 330,000 units, facing slowdown of sale, this subsidy was cancelled in 2020.



Source: Japan Gas Association

Figure 3.4-1 Trend of City Gas Sale by Sector



Source: Advanced Cogeneration and Energy Utilization Centre JAPAN (ACEJ)

Figure 3.4-2 Trend of Cogeneration System in Industry and Commercial Sectors

Major policies on subsidies and tax incentives to promote natural gas penetration available in Japan as at Fiscal Year 2020 are summarized below:

Subsidies

(1) Subsidy for reducing CO_2 emissions using natural gas

a. Executive body: City Gas Promotion Centre
b. Entitlement: To support construction of natural gas facility and equipment that can operate at the time of natural disasters.
c. Subsidy rate: A half of the facility and equipment costs (Max. JPY240 million/year: approximately US$1.55 million/year)
d. Target facility and equipment: Cogeneration, gas cooling and heating system, boilers, etc.

(2) Subsidy for rationalization of energy use

a. Executive body: Sustainable Open Innovation Initiative
b. Entitlement: To support introduction of facility and/or equipment with high efficiency.
c. Subsidy rate: One-third of the cost as factory total (Max. JPY1.5 billion/year: approximately US$13.6 million/year)
   One-third of cost as facility and equipment basis (Max. JPY30 million/year: approximately US$270 thousand/year)
d. Target facility and equipment: Cogeneration, gas cooling and heating, boilers, etc.

Tax Incentives

(1) Tax incentives for cogeneration system

When an entity purchases a cogeneration system under given conditions, standard taxable value of the property tax applicable for the cogeneration system is reduced by one-sixth for the first three years.

Chapter 4 Update on Natural Gas Utilization Master Plan

In this chapter, we review and update the status of natural gas projects scheduled under the final draft of the Natural Gas Utilization Master Plan (NGUMP) released late 2016. More specifically, we review and update the status of upstream gas field development, power supply plan under the Power System Master Plan (PSMP) 2020 and gas based industries such as LNG, which altogether constitute the foundation of natural gas supply in Tanzania.

4.1 Natural Gas Resources and Gas Field Development

Natural gas fields in Tanzania may be divided into two groups in view of the readiness of supply: 1) onshore and shallow water gas fields some of which are already in production and 2) deepwater gas fields in the exploration and appraisal stage. In addition to the gas pipeline connecting Songo Songo gas field and Dar es Salaam, a new trunk line was completed from Mtwara to Dar es Salaam in the summer of 2015. This has brought Mnazi Bay gas field in the supply line up. The 36” pipeline has a design capacity of transporting 784 MMcfd (approximately 0.3 Tcf a year if fully utilised), which can be upgraded to 1,002 MMcfd if gas is compressed. The pipeline capacity to serve the Dar es Salaam metropolitan area and the local market alongside are deemed to be sufficient for a decade or two. On the supply side, only onshore and shallow water fields can be considered for gas supply before 2025, and they will be more than sufficient to accommodate the demand during the early build-up period.

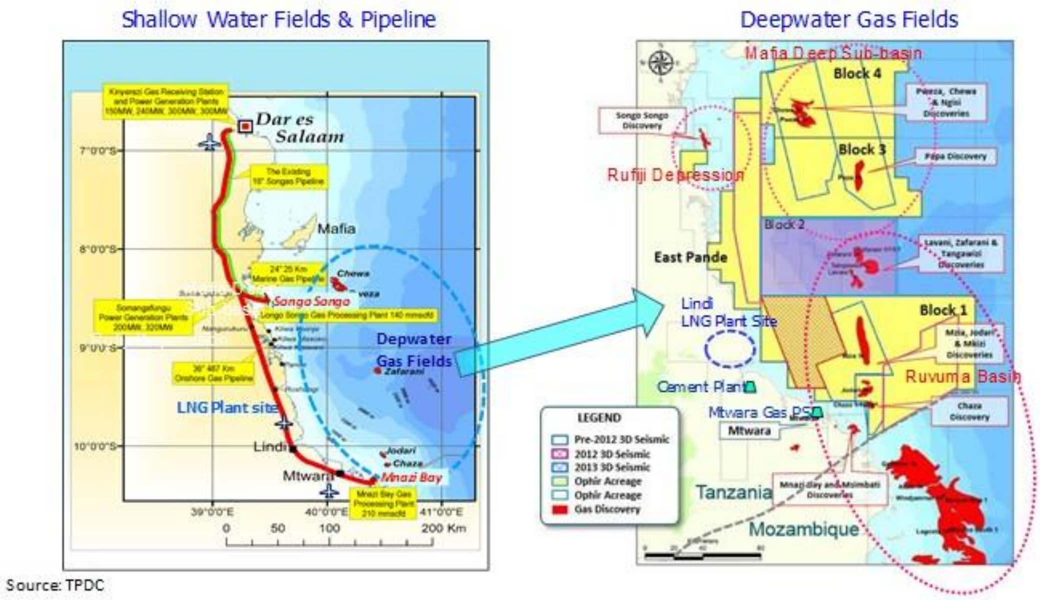


Figure 4.1-1 Gas Fields and Pipelines in Tanzania

Deepwater gas fields may be developed collectively for the large scale LNG project. The Tanzanian government and international oil companies are presently negotiating to formulate Host Government Agreement (HGA) to set out the project framework. As discussed in Section

4.3, the LNG project may start production after 2027.

Natural gas resources of Tanzania as at the end of 2018 was 57.54 Tcf according to TPDC, breakdown of which is shown in Table 4.1-1. If we apply recovery ratio of 70%, recoverable reserves are 7Tcf for onshore/shallow water gas fields and 33Tcf for the deepwater gas fields.

Table 4.1-1 Natural Gas Resources of Tanzania

Category	Gas fields	End of 2018		
		Proven Reserve P50	Resource GIIP P50	Recovery of 70%
Land/Shallow Water		Tcf	Tcf	Tcf
	Songo Songo	0.729	2.500	1.75
	Mnazi-Bay	0.482	5.000	3.50
	Kiliwani North		0.070	0.05
	Mkuranga		0.200	0.14
	Ntorya		0.466	0.33
	Mambakofi		2.170	1.52
	Sub-total		10.406	7.28
Deep Water	Block-1		14.200	9.94
	Block-2		25.400	17.78
	Block-3		2.000	1.40
	Block-4		5.530	3.87
	Sub-total		47.130	32.991
Total			57.536	40.275

Source: TPDC

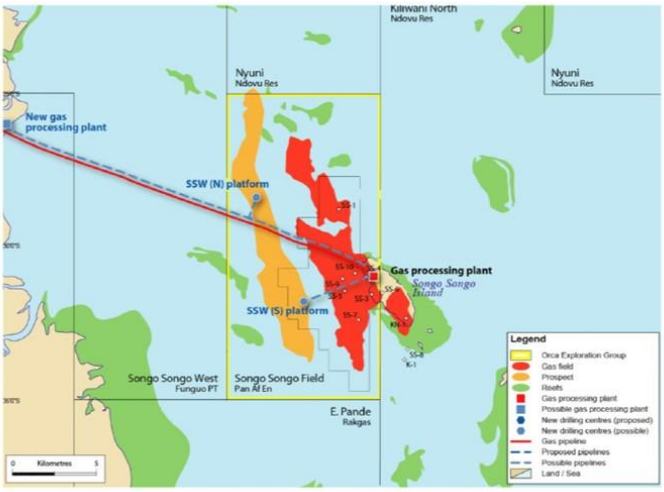
It should be noted that definitions of the recoverable reserves of onshore/shallow water gas fields listed here are not consistent. The reserve assessments for Songo Songo and Mnazi Bay reported in the website of oil companies include only discovered gas fields reflecting the strict accounting rules and regulations by the U.S. Securities and Exchange Commission. On the other hand, internal estimations were announced by oil companies for Ntorya and Mambakofi. The above overall assessment by TPDC includes expectations on prospects and leads which are identified but yet to be drilled. Despite these inconsistencies, the table indicates a plausible expectation amount to be achieved once the prospects and leads identified to date were appraised with certain success ratio.

As these onshore/shallow water gas fields are easier to develop at relatively small cost, they may likely provide the resource basis for the early part of the natural gas promotion in the domestic market. Present status of exploration, development and production of these gas fields and expectations on them are summarized below. Oil and gas exploration in Tanzania is yet in an early stage and big potential is expected as discussed below. The immediate concern is how to create effective demand for the discoveries so that we can encourage further exploration leading to additional discoveries.

4.1.1 Songo Songo and Kiliwani North

1) Current Status

The Songo Songo gas field was discovered in 1974 by Agip (Africa) Ltd (presently ENI), but the Italian company gave up the gas field as not being commercially feasible. In 1995, the Tanzanian government opted for implementation of the Songo Songo gas-to-power project with the principal goal to make it a reliable source of low cost electricity. The World Bank made the final decision to support the project in 2001. The project was started by a consortium of various foreign/local joint ventures ranging from upstream through gas utilization. The gas field was developed by PanAfrican Energy Tanzania Limited, an arm of ORCA Exploration Group Inc., and came on stream in June 2004. Production increased to 61 million cubic feet per day (MMcfd) and then decreased due to slower power demand. It was in the range of 40 MMcfd during 2016-2017.[20]

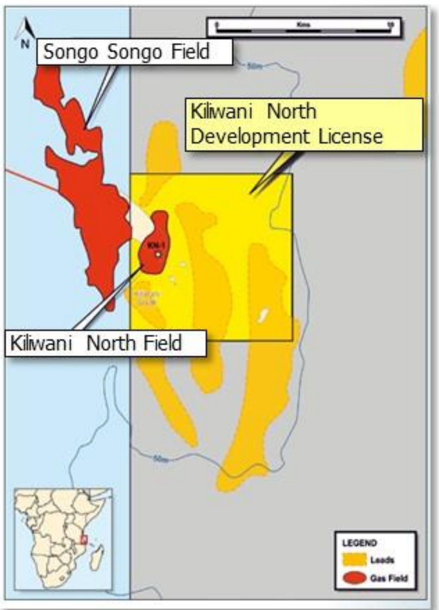


Source: ORCA Exploration Group

Figure 4.1-2 Songo Songo Gas Field

The Songo Songo cluster comprises Songo Songo Main, which is presently producing, Songo Songo North (SSN), where natural gas has been confirmed by drilling but not producing yet, and Songo Songo West (SSW), a promising prospect for future appraisal. The main producer is upper cretaceous sand stone, and the average recovery factor is about 75-80%.

There is another small gas field called Kiliwani North operated by Ndovu Resources (Aminex/Solo Oil). It started production in April 2016. However, gas production sharply declined from middle of 2017 below 1 MMcfd. Ndovu was reportedly considering wellbore workover but the result is unknown. It stated in 2017 that, despite the mishap, deepwater prospects identified in the southeast of the field will be promising and examined in future.[21]



Source: Aminex

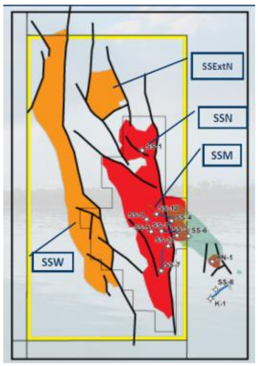
Figure 4.1-3 Nyuni Area leads

[20] Orca Exploration Group Presentation August 2017 (incorporating Q2 2017 results)
[21] Aminex, Annual Report & Accounts 2017

2) Gas Resources

The gas initial in place (GIIP) of the SS+SSN+SSW is presently estimated at around 2.5 Tcf. ORCA Energy, operator, estimates the prospective recoverable resources as shown in Table 4.1-2[22]. These numbers for SSN Extension and SSW need to be confirmed by appraisal drilling.

Table 4.1-2 Natural Gas Reserves and Resources of Songo Songo



Conventioanl Natural Gas Reserves and Resources

Reserves		1P	2P	
	SS Main	203	229	
Resources		Low	Best	High
Contingent	SSM-N	250	297	346
Proospective	SSW+SSN-Ext	118	611	1,437
	Sub-Total	368	908	1,783
Total		571	1,340	2,215

Note: Total for Best is 1P+2P+Contingent +Prospective

Source: ORCA Energy Inc, "A Sustainable Tanzanian Natural Gas Business", Corporate presentation, June 29, 2021

3) Additional Exploration and Development Plan

Simultaneously with the new gas pipeline running from Mtwara to Dar es Salaam, a new branch line from Songo Songo was constructed. There are 11 production wells at the SS main structure. The operator PanAfrican conducted a workover on corroded wells and will add the 12th producing well to increase the gas production from the previous 80-90 MMcfd allocated for Songas to 180MMcfd in 2018.[23] This production rate will be maintained up to 2026 when the present PSA expires. However, it will start a steep decline after then. With some anxiety on earlier decline, PanAfrican is planning to carry out evaluation of the SS North where gas has been confirmed already; running additional seismic survey and drilling an appraisal well. PanAfrican expects that, if SSN is put in production, gas production could be raised by 70MMcfd from 2019. The peak production will reach 260 MMcfd, but the production will start to decline in 2026.

The operator also wishes to appraise a nearby prospect SS West. According to PanAfrican, SSW has a geologically similar structure to SS. However, essential factors which determine the accumulation of gas, such as gas water contact level and fault system are totally unknown because no wells were drilled in this structure yet. If these factors turn out to be favourable, 1Tcf of GIIP is expected. In the other way around, if these factors are not favourable, the present estimate of GIIP of Songo Songo will be halved. To justify these additional exploration projects, the operator says extension of the existing PSA is necessary to ensure the revenue flow for the investment.

Compared with Songo Songo, additional exploration on Nyuni area development license may be deemed as future possibility.

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[22] ORCA Energy Group Inc., A Sustainable Tanzanian Natural Gas Business Corporate Presentation June 29, 2021
[23] ORCA Exploration Group Inc., 2017 Annual Report

4.1.2 Mnazi Bay

1) Current Status

The Mnazi Bay gas field is located at the southernmost part of Tanzania at the estuary of the Ruvuma River, which defines the border with Mozambique. The gas field was discovered in 1982 by Agip, and likewise with Songo Songo, it was relinquished.

In 2002, Calgary-based Artumas Group proposed the Mtwara Gas-to-Power Project to the Tanzanian government. The well Mnazi Bay 1 was re-entered in 2005 and flow tested. The consortium of Maurel & Prom Exploration Production Tanzania Ltd (M&P, operator), Wentworth Resources Ltd (former Artumas changed name in 2010) and TPDC commissioned the project in 2007. However, the production of the Mnazi bay gas filed was limited only at 2 MMcfd until 2015 due to lack of local demand. To utilize this gas resource, a trunk pipeline was constructed under the Natural Gas Infrastructure Project to transport the gas from Mnazi Bay to Dar es Salaam via the newly constructed Madimba gas processing plant. Upon completion of the pipeline through to Dar es Salam in the summer of 2015, production from the Mnazi Bay has increased, but was running at slightly over 103 MMcfd at the end of 2020 being still short of the target 210MMcfd (70Bcf per year).

2) Gas Resources

According to Wentworth, the project partner, the prospective gas resources of the Mnazi Bay License at P50 is 1,512Bcf[24]. On the other hand, the GIIP of the Mnazi Bay gas field is widely announced to be 5Tcf. This publicized figure is likely to be an optimistic expectation aggregating all prospects and leads identified to date. These prospects and leads other than Mnazi Bay are yet to be drilled for appraisal.

Source: TPDC, Wentworth

Figure 4.1-4 Mnazi Bay and Adjacent Gas Fields

[24] RPS Energy Canada/Wentworth Resources Limited, “Mnazi Bay Reserves and Mnazi Bay and Mozambique Prospective Resources as at 31 May 2018”

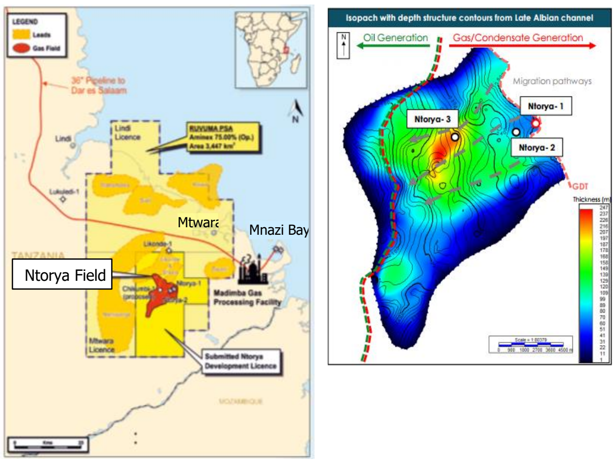
3) Additional Exploration Plan

In addition to the full development of the Mnazi Bay gas field, the operator has run seismic and G&G study on adjacent prospects. They had set up drilling programmes on the offshore as well as onshore prospects and started negotiation with TPDC on gas sale contract once additional gas becomes available. If exploration is successful, new fields will be tied to the new gathering system. At the time of this writing, the outcome of the negotiation is unknown.

4.1.3 Ntorya

Ntorya gas-condensate[25] field was discovered by Ndovu Resources (Aminex/Solo Oil) in the hinterland of Mtwara in December 2011. It is deemed to be in the hydrocarbon rich Ruvuma basin where Mnazi Bay gas field is located. After acquiring 2D seismic data on the license in May 2014 to further appraise the Ntorya discovery and identify the locations for future development wells, the Ntorya-2 appraisal well was spud in December 2016 and encountered a 51m sandstone reservoir at a depth of 2,795m.

Aminex reported in April 2017 a material increase in its estimate of gas resources. According to its annual report, the mean gross gas initially in place (GIIP) reserves of Ntorya are estimated at 466 billion cubic feet (Bcf), while the un-risked GIIP resources are estimated at 1.3Tcf. The company stresses that the estimates cover the Ntorya appraisal area only and do not include the potential of the adjoining exploration acreage. Several large leads are identified in the license block as shown in Figure 4.1-5.



Source: Aminex

Figure 4.1-5 Ntorya Gas field

According to the Aminex's Ruvuma Operations Update[26], "through a re-interpretation of the existing 2D seismic dataset, APT's revised mapping and internal management estimates suggest a mean risked gas in place ("GIIP") for the Ntorya accumulation of 3,024 Bcf (8,236 Bcf unrisked), in multiple lobes to be tested and a mean risked recoverable gas resource of 1,990 Bcf (5,419 Bcf unrisked). In addition to the producing Mnazi Bay gas field, the onshore Ruvuma basin area may become the gas supply centre for the next decade.

[25] The Ntorya-1 discovery well was drilled to a depth of 3,150m and encountered a 3.5m gas-bearing zone. The well was tested and flowed at a maximum rate of 20.1 million standard cubic feet of gas a day (MMcfd), producing 139 barrels of oil a day and 53° API condensate.

[26] http://admin.aminex-plc.com/uploadfiles/211022%20Ruvuma%20Operations%20Update.pdf

4.1.4 Mambakofi

In February 2016, Dodsal Hydrocarbons and Power Tanzania Limited made announcement of a big gas discovery at its wildcat well drilled in the Ruvu Basin Development License. The Mambakofi-1 well was drilled near Mlandizi about 50km west of Dar es Salaam. A specialty journal reported[27] in June 2016 that "the operator as a result of these tests prospective resources for the Ruvu Basin block, in which the well is located, are now put at 2.7 Tcf, with a potential upside of 3.8 Tcf, making this the largest onshore discovery in the country. Further gas resources may be associated with Mtini-1, the second well to be drilled on the block, and the most recent one, Mbuyu-1, on the western side of the block, where a large, possibly tight, gas column was detected but not tested."

Figure 4.1-6 Location of Ruvu Basin Discovery

Dodsal Resources ran 3D seismic for a 481 sq-km on its Ruvu license discovery in 2021, which is reportedly yielding promising results. "To date Dodsal have drilled 3 wells and acquired 2,139 line kilometres of 2D over the area, where yet to find estimates range up to 5 Tcf of gas. Dodsal aims to start its next exploration programme in early 2022 after the initial results from the 3D area are ready in December 2021"[28]. Once the big gas reserves are confirmed at this location, the gas field may provide a significant resource base to consider the Domestic Natural Gas Promotion Plan (DNGPP). Otherwise, if sufficient local demand is not ensured, development of the gas field may face difficulties in commercial development. Under the circumstance, development of Mambakofi appraisal activities should be closely monitored as an important element of this Study.

In addition to these onshore and shallow water gas fields, large deepwater fields will be developed once the LNG project presently under negotiation is given the greenlight. They may be put in production much later than onshore and shallow water gas fields, and will contribute to middle to long term gas supply system development.

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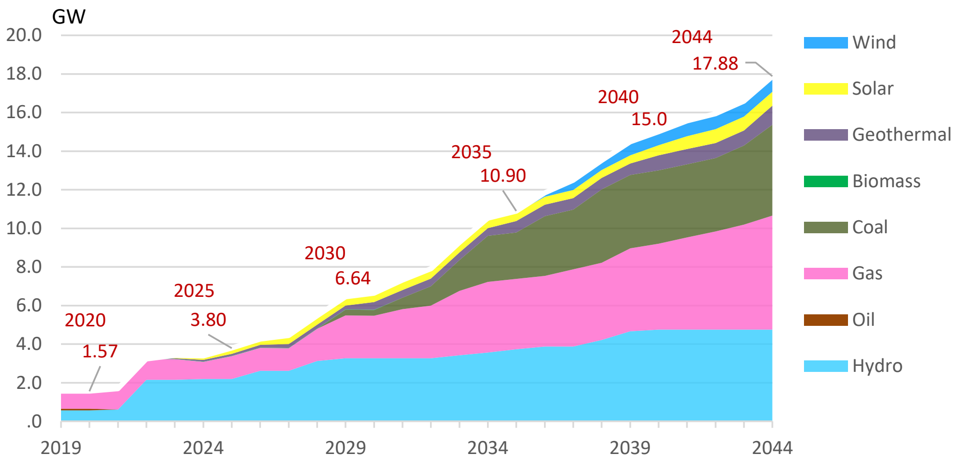
27 GEOExPro, "Tanzania: Largest Onshore Discovery" June 2016
28 Oil News Kenya," TANZANIA: Dodsal Resources Completes 3D seismic on its Ruvu Basin", Nov 09, 2021

4.2 Generation Expansion Plan and Outlook for Development of Gas Fired Power Plants

The Power System Master Plan 2020 Update (PSMP 2020 Update) was announced in September 2020, which develops construction plans of power generation stations and transmission systems up to 2044. The work to update the PSMP 2016 Update was conducted from February through September 2020, and it proposes full review of the plan and formulation of the PSMP 2025 to start in 2023.

The PSMP 2020 Update lists all the construction projects with site name and start-up timing. The projected power generation mix is illustrated in Figure 4.2-1. Between 2020 and 2044, the national generation capacity on-grid will expand 11.4-fold from 1.57MW to 17.9MW. One immediate great event is start-up of the country's largest hydropower project Julius Nyerere Hydro Power Plant (JNHPP) in 2022. Its generation capacity is 2,115MW; with its completion, the country's generation capacity, 1,565.7MW at the end of 2020, will more than double. Hydro power continues to be the single largest power source until the early 2030s.



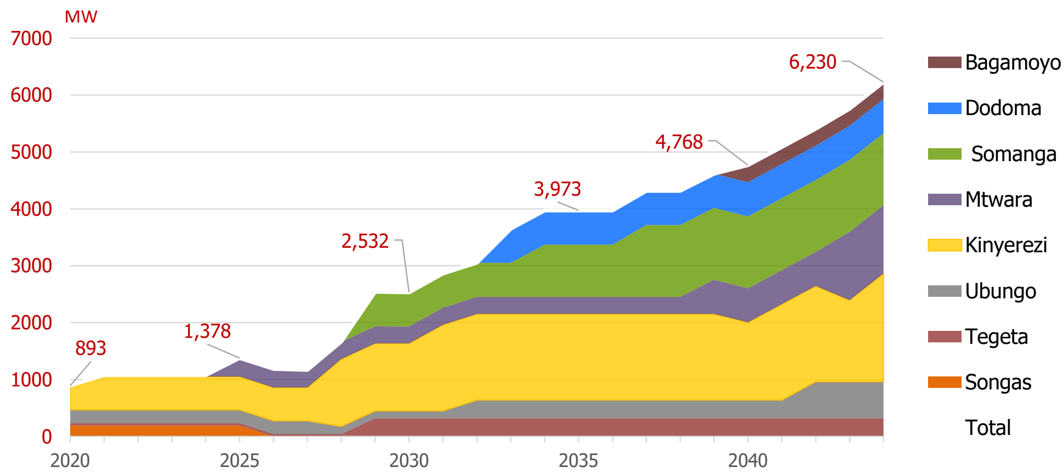
Source: Ministry of Energy, "PSMP 2020 Update"

Figure 4.2-1 Power Generation Mix (On-grid): PSMP 2020 Update

To accommodate the expected robust demand growth, in addition to hydro, gas and coal thermal power stations will play important roles. The gas thermal generation capacity will reach 2.5GW by 2030 and 6GW in the early 2040s and coal thermal generation capacity 4.7GW by 2040.

Among others, the gas power plant construction plan was revised as follows:

1) Near future plans are rescheduled to the latest construction plan.
2) All project names/sites are identified.
3) Two gas power plant plans beyond the existing pipeline are announced, namely, Dodoma power station (600MW) to start in 2033 and Bagamoyo power station (300MW) to start in 2040.



Source: Ministry of Energy, "Power System Master Plan 2020 Update", September 2020

Figure 4.2-2 Gas Power Plant Plan: PSMP 2020 Update

Table 4.2-1 Revised Gas Power Plant Plan

Year	Plant	Type	PSMP 2016		Year	Plant	Type	PSMP 2020	
			Retire	Addition				Retire	Addition
			MW	MW				MW	MW
2017	Kinyerezi I Extension	CCGT		185	2021	Kinyerezi I ext	SC		185
2018	Kinyerezi II	CCGT		240	2024	Songas(Retire)	SC	-189	
2019	Somaga Fungu I	GT		210	2025	Mtw ara I	CCGT		300
	Kinyerezi III Phase 1	CCGT		246	2027	Mtw ara (Retire)	GE	-18	
2020	Somaga Fungu I Steam Add-on	ST		110	2028	Kinyerezi III	CCGT		600
	Kinyerezi III Phase 2 Add-on	CC		123		Ubungo I (Retire)	GE	-102	
2022	Somanga	CCGT		240	2029	Somanga Fungu TANESCO	CCGT		600
2023	Mtw ara	CCGT		300		Tegeta (Retire)	GE	-45	
2024	Songas 1,	SC	-42			Tegeta New	CCGT		320
	Somanga (PPP)	CCGT		300	2030	Mtw ara Additional (Retire)	GE	-4	
	Bagamoyo (Zinga)	CCGT		200		Somanga (Retire)	GE	-8	
2025	Future CGT 1	CCGT		440	2031	Kinyerei IV	CCGT		330
	Songas II	SC	-120		2032	Ubungo I New	CCGT		320
2026	Songas III	SC	-40			Ubungo II (Retire)	SC	-129	
2027	Mtw ara (Retire)	GE	-18		2033	Dodoma	CCGT		600
2028	Future CGT 1 Add-on	CCGT		110	2034	Somanga Fungu PPP	CCGT		320
2029	Future CGT 1 Add-on	CCGT		220	2037	Somanga Mtama	CCGT		345
2031	Future CGT 1 Add-on	CCGT		220	2039	Mtw ara II	CCGT		300
2032	Future CGT 3	CCGT		940	2040	Bagamoyo	CCGT		300
2033	Future CGT 3 Add-on	CCGT		530		Kinyerezi I (Retire)	SC	-150	
2034	Future CGT 1 Add-on	CCGT		110	2041	Kinyerezi I New	CCGT		320
	Future CGT 1 Add-on	CCGT		470	2042	Ubungo New	SC		320
2035	Future CGT 1 Add-on	CCGT		1,410	2043	Mtw ara III	CCGT		600
2036	Future CGT 1 Add-on	CCGT		470		Kinyerezi II (Retire)	CCGT	-248	
2037	Future CGT 1 Add-on	CCGT		470	2044	KinyereZi II New	CCGT		470
2038	Future CGT 1 Add-on	CCGT		470					
2039	Future CGT 1 Add-on	CCGT		940					
2040	Future CGT 1 Add-on	CCGT		470					
Total			-220	9,424	Total			-893	6,230

Source: Ministry of Energy, "Power System Master Plan 2020 Update", September 2020

Among others, the above item 3) is particularly important for the DNGPP project in that, in view of the gas consumption volume, fuel gas will be supplied by new pipelines. According to the Ministry of Energy, the Dodoma gas power station consumes 89.55 MMscfd, or 671,200 tons in LNG equivalent, of natural gas and the Bagamoyo gas pwer station 44.78 MMscfd or 335,600 tons in LNG equivalent. Bagamoyo is smaller but it is located only in 40km from the Tegeta gas terminal in Dar es Salaam; so the pipeline will be the the solution. This decision will significantly affect the structure of the national natural gas supply system.

Development of hydropower continues after the JNHPP and the total generation capacity will more than double and exceed 4.7GW by 2044.

Table 4.2-2 Plans of Hydropwer Plants: PSMP 2020 Update

Year	Location	Capacity	Year	Location	Capacity
		MW			MW
2021	Rusumo(80MW)*	27	2034	Mnyera Taveta	145
	Muronqo/Kikaqati－(14MW)*	7	2035	Sonqwe Sofre （163､3MW)	81.6
2022	Julius Nyerere	2115	0	Irinqa (Nqinayo)	52
2024	Malagarasi	49.5	0	Iringa (Ibosa)	36
2025	Andoya (Retire)	-1	0	Tulila (Retire)	-5
	Matembwe (Retire)	-0.95	2036	Mnyera Kwanini	143.9
2026	Kakono	87	2038	Ikondo Mnyera	340
	Rumakali	222	2039	Mnyera Kisingo	119.8
	Upper Kihansi	120	0	Mnyera Ruaha	60.3
2027	Mwenga (Retire)	-4	0	Mnyera Pumbwe	122.9
2028	Kikonge	300	0	Iringa Kilolo	150
	Songwe Manolo (180.2MW)*	90.1	2040	Sonqwe Bupiqu （34MW）*	17
	Masigira	118	0	Mbarali	38.5
2029	Mnyera Mnyera	137.4	0	Njombe	32
2031	Yovi (Retire)	-0.95	2041	Uwemba (Retire)	-0.84
2033	Mpanga	160	Net Increase Total		4,759

Source: Ministry of Energy, "Power System Master Plan 2020 Update", September 2020

All the oil-driven small power plants, obsolete and inefficient nine (9) plants amounting to 88.8MW, will retire in 2021.

Another important plan is to develop coal resources located in the south-western interior regions and develeop coal fired thermal plants. Presently coal resources in these regions are estimated to be 1.2 billion tons. Present coal production is about 700 tons[29] and even sold to the cement industry in Tanga transported by truck over 1,200km. Mine-mouth dmand for power generation will enhance the significant development of the coal industry as well as local electrification. In addition to Mchuchuma, Ngaka and Kiwira, new coal mines will be developed in Njombe, Mbeya and Rukwa Regions. The total generation capacity of coal fired power plants will reach 4.7 GW in 2044.

[29] According to IEA World Energy Balances 2021, coal production was 439 ktoe (712,000 tons at 6,162 kcal/kg) in 2019.

Table 4.2-3 Plans of Coal Fired Power Stations: PSMP 2020 Update

Year	Location	Fuel	Technology	Capacity
				MW
2029	Mbeya I	Coal	Steam	300
2031	Mchuchuma I	Coal	Steam	300
2032	Kiwira I	Coal	Steam	200
	Ngaka I	Coal	Steam	200
2033	Mbeya Ⅱ	Coal	Steam	600
2034	Kiwira Ⅱ	Coal	Steam	200
	Rungwe	Coal	Steam	600
2036	Rukwa Ⅱ	Coal	Steam	300
	Nqaka Ⅱ	Coal	Steam	400
2038	Mchuchuma Ⅱ	Coal	Steam	400
	Kiwira Ⅲ	Coal	Steam	300
2043	Mchuchuma Ⅲ	Coal	Steam	300
2044	Rukwa Ⅱ	Coal	Steam	600
	Total			4,700

Source: Ministry of Energy, "Power System Master Plan 2020 Update", September 2020

Table 4.2-4 Plans of Renewable Energy Power Plants: PSMP 2020

Type	Year	Location	Capacity	Type	Year	Location	Capacity
			MW				MW
Solar	2023	Sinqida	150	Geothermal	2023	Songwe	5
	2024	Dodoma I	55			Ngozi (wellhead) & Ngozi I	30
	2027	Shinyanga I (Kishapu)	150		2024	Kjeio－Mbaka	60
	2031	Dodma Ⅱ	60		2026	Ngozi Ⅱ	40
	2040	Manyoni	100		2027	Natron	60
	2041	Shinyanqa Ⅱ	150			Luhoi	5
	2042	Same Kilimanjaro	50		2030	Geothermal Phase I	195
		Total	715		2035	Geothermal Phase Ⅱ	200
Wind	2025	Singida I	100		2040	Geothermal Phase Ⅲ	185
	2036	Sinqida Ⅱ	100		2044	Geothermal Phase Ⅳ	215
	2037	Makambako	300			Total	995
	2039	Sinqida Ⅲ	200	Biomass	2030	TANWAT (Retire)	-1.5
	2041	Njombe I	100		2031	TPC (Retire)	-9.0
		Total	800			Total	-10.5
					Grand Total	Addition	2,510
						Retire	-10.5
						Net	2,500

Source: Ministry of Energy, "Power System Master Plan 2020 Update", September 2020

Proactive introduction of renewble energy sources is also planned. Solar and wind power projects are programmed in the resource rich interior highland areas. Geothermal development is also planned along the East African rift system. Presently there are 10 biomass based power plants in Tanzania using bagasse and byproducts/residue of wood, sisal and coconuts with the total generaation capacity of 105MW, of which two plants, TANWAT and TPC run on wood residue and bagasse, respectively, are on-grid. In the PSMP 2020 Update these two plants are scheduled to retire after 2030 because of usable life of the plants. However, in view of the avilability of the fuel source and local electricity demand, they are likely to be renewed.

The PSMP 2020 Update illustrates the grand design of the power system development in Tanzania that hydro, natural gas and coal will play core roles to create the platform while renewable energies will be introduced proactively. There are substantial uncertainities in the pathway of developing the system more than 10-fold. To keep the voyage on the fairway, fine tune of the plan will be requied from time to time; requirement for natural gas should be reviewed, accordingly.

4.3 Prospect of NGUMP Projects

The JICA study team proposed an action plan as below in its recommendation for the Natural Gas Utilization Master Plan (NGUMP).

For immediate actions:

1) LNG Project
Set up a Framework Agreement to decide the commercial structure, establish an LNG project implementing body, formulate an LNG project plan and marketing/lifting policy, and kick-off LNG marketing.

2) Gas Field Development
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.

3) Front Runner Projects
Solicit investors for a fertiliser project and/or a co-production plant of methanol, ammonia and fertiliser, and firm up the project.

4) Shallow Water Gas fields
Conduct appraisal of shallow water prospects to secure feed gas for early projects.

For medium and long term actions:

1) Gas Industry Development Plan
Study on a comprehensive plan for development of gas based fuel projects and chemical projects.

2) National Gasification
Study on gas delivery plans to various sectors of the economy and pilot projects.

3) Infrastructure and Human Resource Developments
Formulate infrastructure and human resource development plans to support promotion of

natural gas utilization.

4) Periodical Review

Since many elements are yet in immature status, only the direction of the work plan is described here. The Master Plan and Roadmap should be reviewed, deepened and updated periodically incorporating new information, decisions made, and other relevant developments.

At present, progress of the actions on the above is still in an early stage. For the LNG project, the governement team of Tanzania and international oil companies (IOCs) are in negotiations on the Host Government Agreement (HGA) since September 2017 to set forth the key terms of the project framework. With regard to Front Runner Projects, the Study team understand that the government of Tanzania is discussing with applicants on the possibility of constructing a world class fertilizer plant but the final agreement is yet to be reached. Under the uncertain outlook on these projects, activities are behind the original schedule.

Considering the present progress, the LNG project may start production in 2027 or later as shown in Figure 4.3-1. Suppose that the key terms of the HGA will be agreed shortly, which is set for 2019 in the figure, it may take one year to complete pre-FEED and another two years to prepare the FEED and other key arrangements before making the Final Ivestment Decision (FID). An LNG plant construction takes five (5) years after the FID.

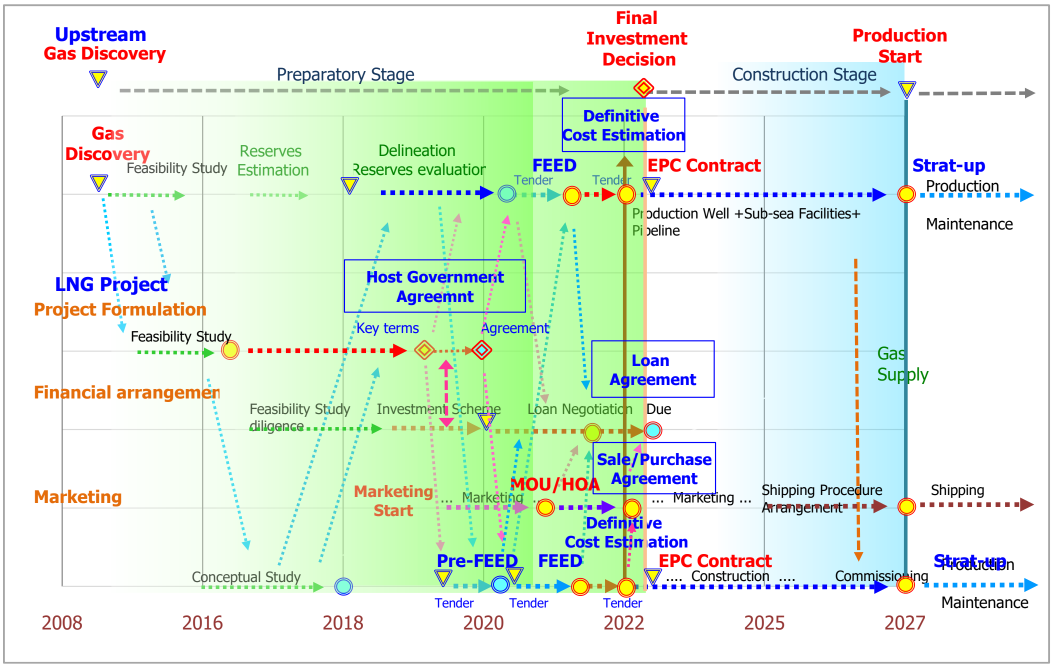


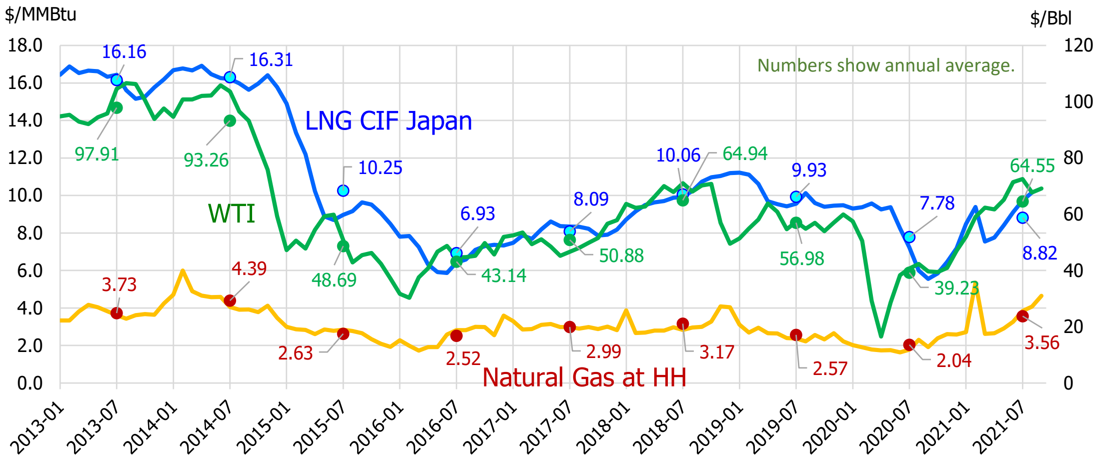
Figure 4.3-1 LNG Project Work Plan: As of 2019

4.4 Revised Economic Study on NGUMP Projects with Updated Assumptions

4.4.1 Price Scenarios

For the Natural Gas Utilization Master Plan study, project economics were run in the early 2015 applying the price scenarios structured by taking into account the prevailing energy market trend back then. As can be seen in Figure 4.4-1, crude oil price represented by WTI plunged in a very short period from as high as $100/Bbl in the middle of 2014 to $30/Bbl in February 2016. It bounced there, but oil price continued to hover at around $60/Bbl until the end of 2019. Then, facing outbreak of COVID-19 pandemic, oil price plunged again to $16.60 in April 2020 as shown in Figure 4.4-1. As discussed in Chapter 2, oil price will gradually increase toward $100/Bbl by 2050.

As shown in Figure 4.4-1, LNG price landed in Japan followed the same trend with a six (6) month time lag with milder fluctuation reflecting the linkage to oil price in the long term contracts. In the increasing spot and short term transactions, such trend tends to be taken in advance and more directly.



Source: IEEJ, USEIA. Dots show averages for year.

Figure 4.4-1 Recent Movement of Key Energy Prices

2021 Price Scenario

The IEEJ price scenarios developed for the 2021 assessment as discussed in Chapter 2 are shown in Figure 4.4-2 for crude oil and 4.4-3 for natural gas. Compared with the 2015 projection, it is significantly lowered taking into account the double dip recession experienced in 2015-2016, overproduction of US shale oil and gas, and eventually the COVID-19 pandemic. In the long run, oil price in real term will increase but at a milder pace in view of strong and abundant supply of unconventional oil on one hand and demand stagnation on the other with fast growth of renewable energies and electrical vehicles (EVs) following the global movement toward Net Zero society.

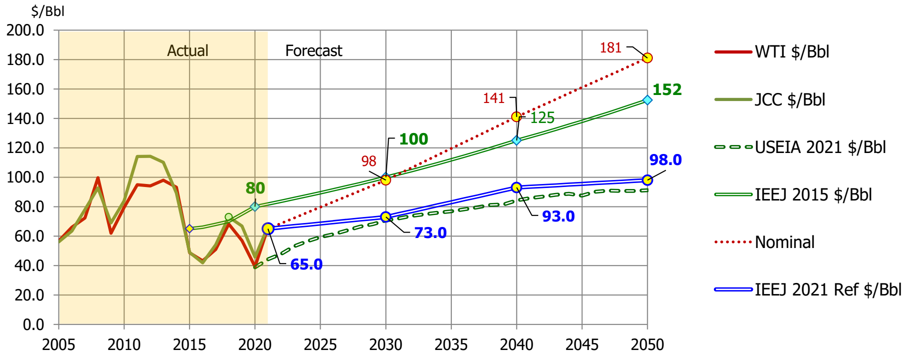


Figure 4.4-2 Crude Oil Price Scenario

Long term natural gas price scenario is revised downward significantly and projected almost flat through the projection period. In late 2021 spot prices of natural gas and LNG are flying high reflecting the extreme gas stock shortage in Europe toward the winter. However, the present energy price turbulence may cease sooner or later as two major gas trunk lines from Russia, Turk Stream and Nord Stream 2, are put in full operation. In the long run, natural gas price in real term will remain slow as natural gas resource base has expanded greatly thanks to the Shale Revolution and that LNG export from the United States and Canada will keep pressure on the global natural gas market.

Under the backdrop, the world gas import market may expand much faster than the previous expectation as seen in the rapid expansion of FSRU based LNG import. On the other hand, investment in fossil energy development is likely to contract facing the global voices toward a Net Zero society. We should carefully observe the post-COVID-19 market trend before we can recognize the revised speed of world gas market expansion.

In addition to the above, fertilizer price is maintained at $350 per tonne while methanol price from $400 per tonne to $350 per tonne delivered to the market; freight cost is deducted to calculate the FOB price at 10% for fertiliser and 15% for methanol. Urea market was dull until 4Q 2020 at around $250 per tonne FOB Middle East. However, the market turned stronger in 1Q 2021, and the price exceeded $400 in July 2021. Methanol price was also dull in recent years below $300 per tonne. It started to recover in 1Q 2021 and was $360 per tonne in May 2021.

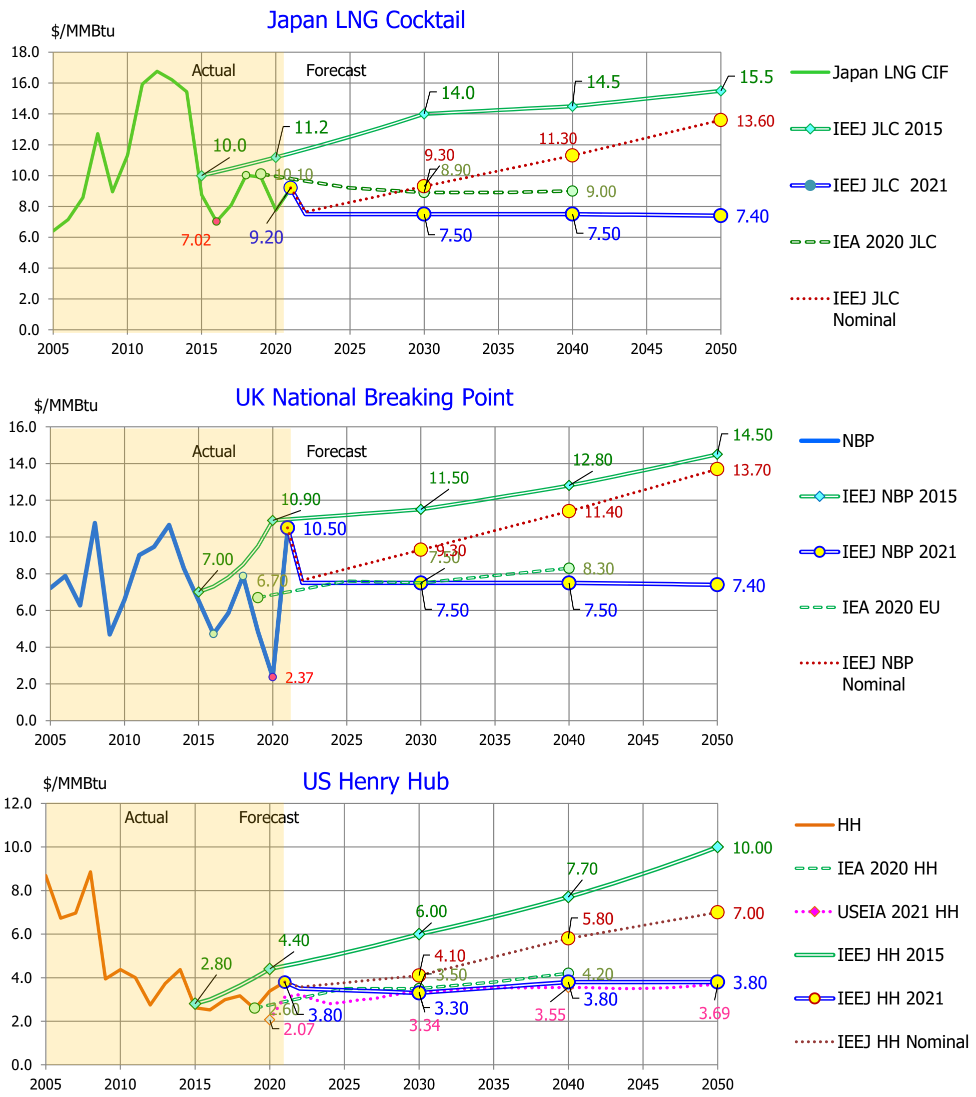


Figure 4.4-3 Natural Gas Price Scenario

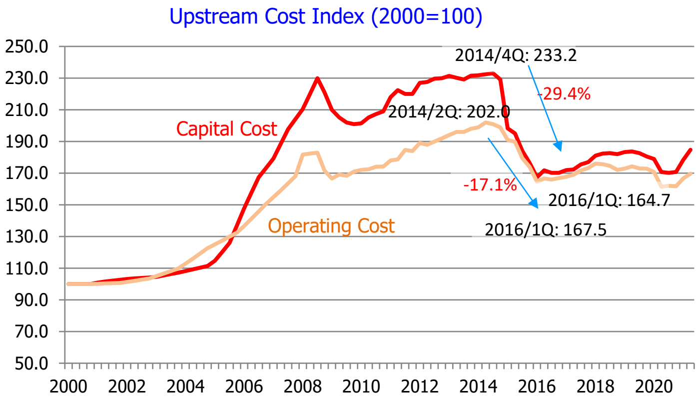
4.4.2 Project Economics

Project economics are calculated applying the above mentioned new price scenario. As inferred from the downward revision of the price which is the most influential factor in project assessment, economics deteriorate significantly for LNG projects. Only real term based analyses were conducted in the past. Under the circumstance, additional cases are calculated this time to consider inflation. This method is generally adopted in monetary evaluation of project economics though the applicable inflation rate is always controversial.

At this point, however, it is also necessary to consider the effect of energy price plunge on the construction side. Since 2015 and onwards, drilling rig utilisation and rig day rate have shown steep decline to almost a half of the booming time as their jobs sharply decreased facing budget cuts by oil companies.

Source: IHS Markit

Figure 4.4-4 Drilling Rig Day Rates



Source: IHS Markit

Figure 4.4-5 Upstream Cost Index

According to the assessment by IHS CERA, upstream capital cost and operation cost have substantially declined since 2014. From these observations, we may consider substantial cost reduction for construction of gas based industries. As such, additional cases are calculated assuming a 20% cost reduction although no new detail cost assessment is available at this moment. Outcomes of these recalculations of project economics are summarized in Table 4.4-1.

Table 4.4-1 Project Economics of Gas Based Industries

	LNG			Fertilizer		Methanol	GTL		DME	MTG	Gas Field
				Ammonia	Urea						
Nameplate Capacity	5.0 MTPA			2,300 t/d	4,000t/d	3,000t/d	15,000bpd		250ktpa	230ktpa	3 gas fields to feed a 5 MTPA LNG plant
Production	tons			tons	tons	tons	barrels		tons	tons	
Annual (330days/year)	5,000,000			759,000	1,320,000	990,000	4,950,000		250,000	230,000	
Daily	15,152			2,300	4,000	3,000	15,000		4	697	
Trains	2	3	4		1	1	2	3	1	1	4
Gas Consumption (25 years: Tcf)	13.16	20.34	23.68	→	0.65	0.81	2.17	2.65	0.29	0.50	31.68
Investment Amount ($ billion)	13.40	17.71	24.62	→	1.34	0.90	4.24	6.22	0.38	0.87	30.57
Project IRR					($300/t)	($350/t)					
OLD PRICE	**11.4%**	**12.4%**	**12.2%**		**13.1%**	**13.6%**	**12.3%**	**12.7%**	**11.6%**	**8.2%**	**10.7%**
NEW PRICE	**8.9%**	**9.1%**	**9.4%**		**9.7%**	**9.1%**	**10.3%**	**12.0%**	**7.5%**	**7.4%**	**8.8%**
CAPEX ·OPEX 80%	**11.2%**	**11.2%**	**11.9%**		**11.5%**	**12.5%**	**12.8%**	**15.1%**	**10.5%**	**11.1%**	**10.4%**
Pre-Tax	**13.9%**	**13.8%**	**14.6%**		**15.1%**	**15.2%**	**15.5%**	**15.3%**	**12.7%**	**11.2%**	**10.8%**

Since gas prices are revised downward while oil prices are projected relatively high in the revised scenario, economics are diverse among projects. LNG supply/demand balance is anticipated to slacken after commissioning of huge production capacities in the next few years in the United States, Australia, and Qatar. The applied price scenario follows this assessment.

Business circumstance changes day to day, year to year; it is a challenging task to set out a dependable and agreeable standard price scenario. Likewise, plant construction costs, which were significantly inflated during the last decade, may further change reflecting the depressed market in the aftermath of the LNG plant boom, or alternatively the boom may continue into another decade. To obtain more accurate cost estimation, it is also necessary to conduct an in-depth study including assessment of site-specific conditions.

As calculated above, at 20% lower CAPEX, pre-tax economics mostly appear to be in a fairly good range. This means that project economics are feasible from the national viewpoint, while legal and financial framework need to be set out appropriately to make these projects viable as business and endorsable for the government. At this point, we should note that main part of the sizable products will be sold in the global market. In this regard, international market circumstance should be carefully assessed to establish suitable conditions for these projects.

4.4.3 Way Forward

From the above analysis, recommendations made for the Natural Gas Utilization Master Plan should be maintained while strong political actions will be needed to ensure investment and/or to invite new investors to open up the gas based industry. In particular, LNG is a "Long Negotiation Game" but Tanzania does not have a luxury of giving it up. LNG is the only way to tap the huge deepwater gas resources. In the world, many front-running project proposals are being withdrawn, and Tanzania is now on the upper part of the waiting list. Tanzania should take up this opportunity as soon as possible developing firm and consistent policies to sell the Tanzanian LNG. Upon implementing this, it is most important to prepare an investment framework that complies with international business standard and makes the gas projects bankable from the international financial viewpoint.

Since many elements are yet in indeterminate status, the above assessment should be reviewed, deepened and updated periodically incorporating new developments.

Chapter 5 Outlook of Domestic Gas Demand

As the basis to consider domestic natural gas promotion in Tanzania, the country's long-term energy trends are discussed in this chapter. First assessment was made in 2018 which is explained in Section 5.1. Then, facing outbreak of COVID-19 in 2020, the macro analysis on energy trend is updated as shown in Section 5.2. It indicates that the energy demand growth may delay 2 years or so from the previous projection. Sections 5.3 and 5.4 show a macro assessment on regional energy demand. An in-depth analysis is made in Section 5.5 on the objective regions incorporating the outcome of the Regional Energy Demand Survey (REDS) conducted in 2018 and Market Research in 2021.

5.1 Outlook of National Energy Demand (Before COVID-19)

5.1.1 Model Structure and Major Assumptions

1) Model Structure

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 modelling 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 by energy source is estimated 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. In view of the objective of this Study, we concentrate on the projection of the final energy demand only.

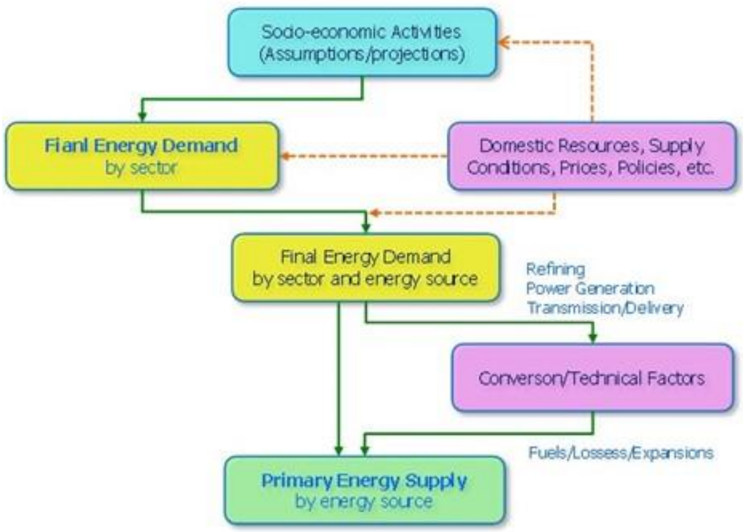


Figure 5.1-1 Flowchart: Energy Demand Model

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 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.

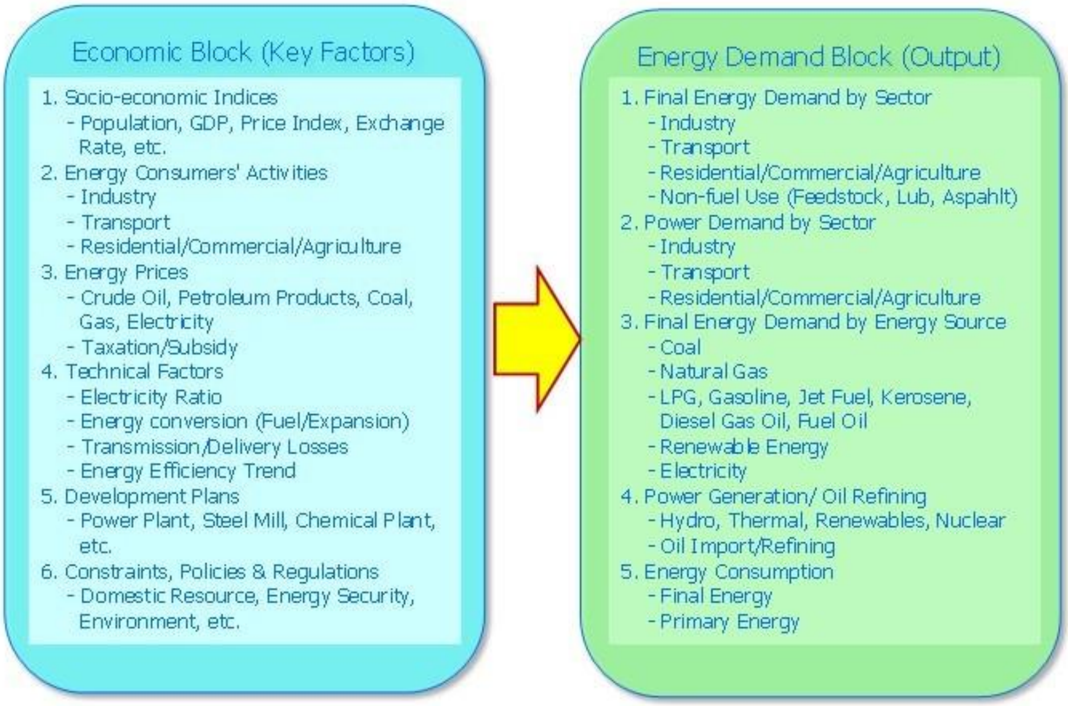


Figure 5.1-2 Key Elements and Output of the Energy Demand Model

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.

2) Major Assumptions

(1) Population

The population of Tanzania is assumed to maintain a steady growth of close to 2.7% per year (the average between 2000 and 2015) during the present decade. Thereafter the growth will gradually slow down as the economy develops with urbanisation and modernisation of lifestyle. The population will almost double in the coming three decades from 48.8 million in 2015 to 93 million in 2045 and reach almost 100 million in 2050.

Table 5.1-1 Assumption for Population Growth

		2000	2015	2025	2035	2045	2050	2015 ⇒2050
Population	million	32.54	49.36	66.07	82.20	97.05	103.53	
AAGR	1990→	2.9%	2.8%	3.0%	2.2%	1.7%	1.3%	2.1%

Urbanization ratio is still low in Tanzania but will play an important role in its economic development process. Fuel will be increasingly switched to modern energies and more electricity will be used as source of power for appliances as people move to cities and modernise their life style.

The urbanisation ratio of Tanzania, i.e. 34.5% in 2019, is assumed to increase to 50% in 2040 and to 55% in 2050; the urbanisation speed curve is derived assuming that it will eventually reach 70% in 2100, which is more or less a standard observed in Southeast Asian countries. Under this scenario, rural population will peak around 2060 and then gradually decline, while urban population continues to grow.

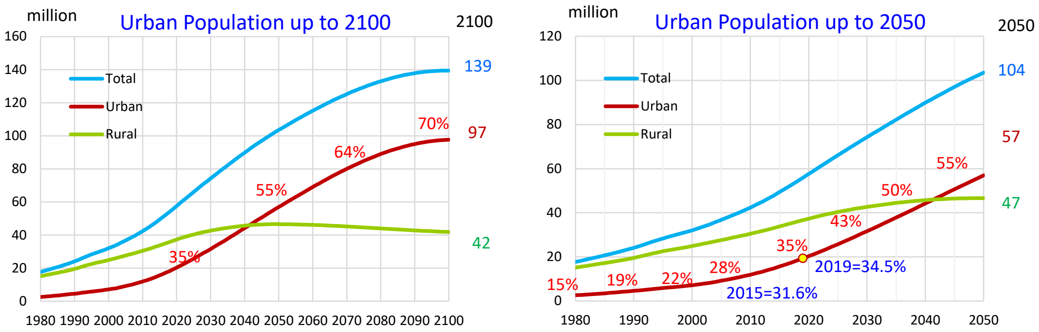


Figure 5.1-3 Urbanisation Ratio

(2) GDP: Pre-COVID-19 Projection

The real GDP[30] of Tanzania recorded a steady growth at an average 6.5% per annum from 2000 to 2015. According to "The Tanzania Development Vision (TDV) 2025" [31] set out in 1995 by the NEEC (National Economic Empowerment Council), the government aims at an economic growth rate of more than 8% per annum through 2025 to realise 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-industrialised one. A solid foundation for a competitive and dynamic economy with high productivity should be established with an adequate level of physical infrastructure. The government expectations developed in various plans are summarised in Table 5.1-2.

30 IMF: The real GDP in 2010 US Dollar.

31 Planning Commission, "The Tanzania Development Vision 2025", 1995

Table 5.1-2 Government Plans for Economic Development

Sources	Prospects of GDP Growth Rates
Vosion 2025	30 years later, Tanzania becomes a middle developed country with per capita GDP at $3,000. GDP grwoth rate shall be more than 8% to reach the goal.
Long Term Perspective PLan 2011/12-2025/26	2010-2015 Infrastructure and energy 2015-2020 Natural gas based industry and agro indutry 2020-2025 Manufacturing, service and export
Five Year Development Plan 2012-17	The growth rate was 7% for 2000-2010. Then, at least 10% is required for 2012-2025

Considering these plans, a Reference Case scenario is set out assuming that the real GDP growth rate will keep the present pace of annual 6.5% till 2025 as projected by the IMF.[32] Then it will start a slight decline thereafter mainly because of diminishing population growth rate; the overall average annual growth rate (AAGR) through 2050 will be 6.1%. According to the concept of the Cobb-Douglas production function for long term economic development, an economic growth rate is a sum of growth rates of capital formation, work force and the total factor productivity.[33] In the Reference 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 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.

Table 5.1-3 GDP Growth by Sector

	Agriculture	Mining	Manufacturing	Construction	Services	GDP
	%	%	%	%	%	%
2010-2015	3.1	7.0	6.2	14.1	8.0	6.8
2015-2020	7.1	12.0	8.8	10.0	8.4	6.8
2020-2030	5.8	8.2	6.4	8.0	6.2	6.4
2030-2040	5.5	6.1	6.1	4.3	6.8	6.1
2040-2050	5.2	5.8	5.8	4.0	6.3	5.8
2015-2050	5.7	7.4	6.5	6.1	6.7	6.2

Breakdown of the economic growth among sectors are projected as shown in Table 5.1-3 and figure 5.1-4. Among sectors, the services sector will dominate in the course of the economic development, while mining and manufacturing will also grow steadily though their shares are relatively small. If large scale gas-based industries are introduced, this picture will change significantly.

[32] IMF, "World Economic Outlook 2016"

[33] 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, $(\boldsymbol{t})$ = 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 $\alpha+\beta+\gamma$.

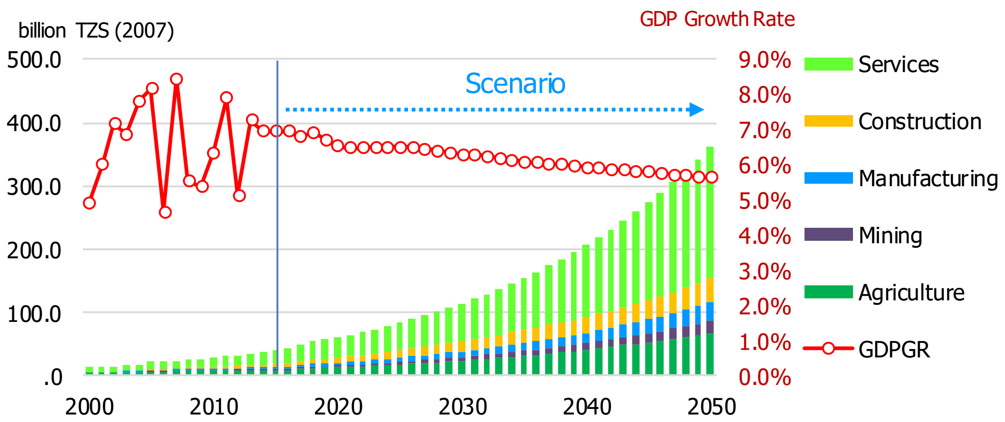
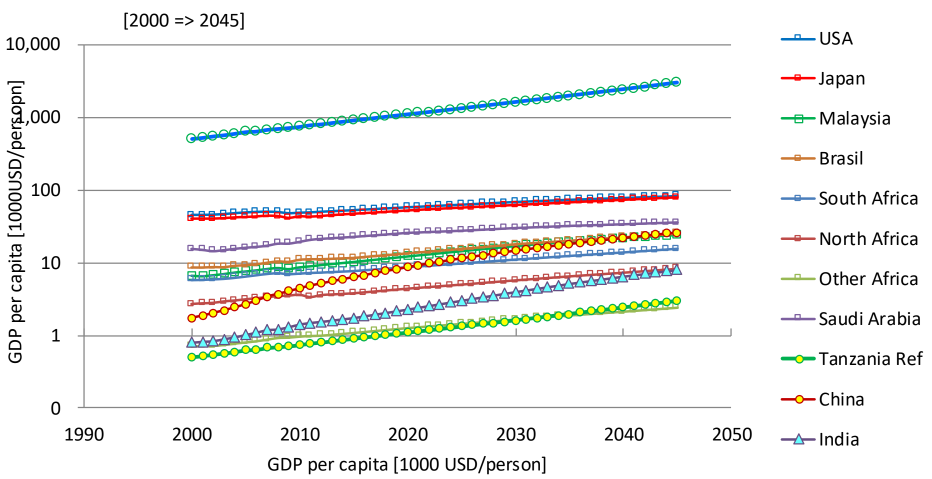


Figure 5.1-4 GDP Growth by Sector

The real GDP per capita will reach $1,600 US in 2030, $2,400 US in 2040 and $3,700 US in 2050. The nominal GDP per capita will exceed $3,000 US around 2025 and reach $10,000 US around 2040. Figure 5.1-5 compares the growth path of per capita GDP of Tanzania with other major economies. Tanzanian economy will overtake the present level of India around 2030 and catch up the present level of China by 2045. Substantial industrialisation and urbanisation is expected to occur, sooner or later, to bring about better quality of life.



Source: "Asia/World Energy Outlook 2017", IEEJ is referred for the countries other than Tanzania.

Figure 5.1-5 International Comparison of GDP per capita

(3) Energy Prices

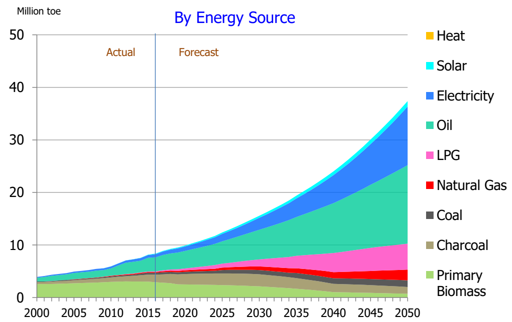
The Pre-COVID-19 energy price scenarios are shown in charts explaining the Post-COVID-19 projections explained in the next section.

5.1.2 Final Energy Consumption: Pre-COVID-19 Projection

The outcome of the pre-pandemic projection is shown in Figure 5.1-6 and Tables 5.1-4 and 5 below. The final energy consumption of Tanzania calculated to be 8,347 ktoe for 2016 will increase to15,569 ktoe in 2030, 24,003 ktoe in 2040 and 37,381 ktoe in 2050. The annual average growth rate for the whole projection period will be 4.5%. Fuel consumption increases 3.3-fold during the projection period at AAGR of 3.6%, while electricity consumption will increase 17-fold at AAGR of 8.7% reflecting urbanisation and modernisation. While the popuration growth rate and economic growth rate will slightly slow down in the later part of the period, energy consumption growth rate will remain high as modern energy consumption will be stimulated through popularisation of modern home and office appliances as well as progress of industrialisation.

Table 5.1-4 Final Energy Demand: by Energy Source

	Actual		Forecast				Average Groth Rate					
	2000	2016	2020	2030	2040	2050	2000→ 2016	2016→ 2020	2020→ 2030	2030→ 2040	2040→ 2050	2016→ 2050
	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%
Coal	109	359	424	796	1,062	1,270	7.7	4.2	6.5	2.9	1.8	3.8
Natural Gas	0	146	288	691	1,151	2,034		18.5	9.1	5.2	5.9	8.0
LPG	3	121	363	1,348	3,648	4,940	26.0	31.6	14.0	10.5	3.1	11.5
Oil	711	2,651	3,337	5,645	9,495	14,950	8.6	5.9	5.4	5.3	4.6	5.2
Primary Biomass	2,555	2,901	2,489	2,122	1,027	711	0.8	-3.8	-1.6	-7.0	-3.6	-4.1
Charcoal	376	1,458	1,975	2,296	1,574	1,292	8.8	7.9	1.5	-3.7	-2.0	-0.4
Combustible Fuel Total	3,754	7,636	8,876	12,898	17,957	25,197	4.5	3.8	3.8	3.4	3.4	3.6
Electricity	162	616	866	2,287	5,340	11,159	8.7	8.9	10.2	8.8	7.6	8.9
Solar	0	95	159	384	706	1,025		13.9	9.2	6.3	3.8	7.3
Electricity total	162	710	1,026	2,671	6,047	12,184	9.7	9.6	10.0	8.5	7.3	8.7
(GWh)	1,885	8,261	11,927	31,058	70,310	141,673	9.7	9.6				8.7
Heat	0	0	0	0	0	0						
Total	3,916	8,347	9,901	15,569	24,003	37,381	4.8	4.4	4.6	4.4	4.5	4.5
(Composition)												
Coal	2.8	4.3	4.3	5.1	4.4	3.4						
Natural Gas	0.0	1.8	2.9	4.4	4.8	5.4						
LPG	0.1	1.4	3.7	8.7	15.2	13.2						
Oil	18.2	31.8	33.7	36.3	39.6	40.0						
Primary Biomass	65.2	34.8	25.1	13.6	4.3	1.9						
Charcoal	9.6	17.5	20.0	14.7	6.6	3.5						
Combustible Fuel Total	95.9	91.5	89.6	82.8	74.8	67.4						
Electricity	4.1	7.4	8.8	14.7	22.2	29.9						
Solar	0.0	1.1	1.6	2.5	2.9	2.7						
Heat	0.0	0.0	0.0	0.0	0.0	0.0						
Total	100.0	100.0	100.0	100.0	100.0	100.0						



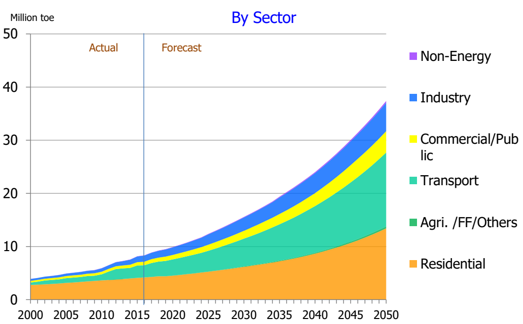


Figure 5.1-6 Final Energy Demand: Total

Among fuel sources, consumption of oil products such as gasoline and diesel will increase fast reflecting motorisation and electrification reflecting diffusion of modern appliances. Use of traditional biomass will decrease at first slowly and then faster in the later period being replaced by modern fuels such as natural gas and LPG. In this projection, city gas supply is assumed to start in 2025 and will increase at an annual rate of 10%. It is necessary to examine if this scenario is realistic and practicable. Imported LPG may be the fuel to supplement it. If more indigenous natural gas could be used to supply for the requirements at homes and business facilities, import of LPG may be reduced accordingly.

Table 5.1-5 Final Energy Demand: by Sector

	Actual		Forecast				Average Groth Rate					
	2000	2016	2020	2030	2040	2050	2000→ 2016	2016→ 2020	2020→ 2030	2030→ 2040	2040→ 2050	2016→ 2050
	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%
Industry	371	1,154	1,424	2,492	3,758	5,361	7.4	5.4	5.8	4.2	3.6	4.6
Transport	479	2,297	3,030	5,223	8,794	13,915	10.3	7.2	5.6	5.3	4.7	5.4
Commercial/Public	290	656	847	1,487	2,442	4,005	5.2	6.6	5.8	5.1	5.1	5.5
Residential	2,747	4,168	4,505	6,179	8,649	13,420	2.6	2.0	3.2	3.4	4.5	3.5
Agri. /FF/Others	12	23	33	75	166	351	4.0	9.1	8.7	8.2	7.8	8.3
Non-Energy	17	49	63	112	195	329	6.8	6.4	6.0	5.7	5.4	5.8
Total	3,916	8,347	9,901	15,569	24,003	37,381	4.8	4.4	4.6	4.4	4.5	4.5
(Composition)												
Industry	9.5	13.8	14.4	16.0	15.7	14.3						
Transport	12.2	27.5	30.6	33.5	36.6	37.2						
Commercial/Public	7.4	7.9	8.6	9.6	10.2	10.7						
Residential	70.1	49.9	45.5	39.7	36.0	35.9						
Agri. /FF/Others	0.3	0.3	0.3	0.5	0.7	0.9						
Non-Energy	0.4	0.6	0.6	0.7	0.8	0.9						
Total	100.0	100.0	100.0	100.0	100.0	100.0						

Energy outlook by sector is discussed in the next section.

5.2 Post COVID-19 Energy Outlook

Since the projection of the long term energy outlook was made in 2018 as above, the world energy market has encountered twin serious crises; outbreak of the COVID-19 and the collapse of world energy prices. The pandemic started in the first quarter of 2020 has parallized world economy and significantly depressed energy demand. This has triggered collapse of the world oil price in April, which was already stagnant reflecting the oversupply caused by robust increase in US shale oil production.

The pandemic may remain longer with emergence of stronger mutant strains and slow development of vaccination. The world is yet amid the fight against the pandemic. Though signs of recovery are seen in some economies, they are not steady and strong. On the other hand, energy prices have rebounded in the first quarter of 2021 reflecting the cold winter and passive mind on energy investment. Given the high degree of uncertainity on every element, we try to review the former projection and evaluate the long term effect of the pandemic as explained below.

5.2.1 Changes in Major Assumptions

Short term effect of the pandemic on the Tanzanian economy is assessed typically by the IMF and the African Development Bank. The IMF has revised its view severer in April 2021 from the World Economic Outlook announced in April 2020. The AfDB assessment released in July 2020 with a milder view was revised downward in December as shown in Table 5.2-1.

At the time of this report, the world econnomy is suffering from disruption of the globally disributed supply system. In particular, production of parts and semiconductors, loading and unloading of goods at ports, and airbone transport are seriously affected in the countries of rampancy. Tourism is yet to come back. Under the circumstance, we adopt the latest and lowest projection made by the IMF in april 2021 and assume that the country’s economic growth will return to the long term baseline scenario gradually by 2025 at around 6.0% per annum. Following this scenario, GDP for 2030 will be 15% smaller than or almost 2 years behind the previous scenario.

Table 5.2-1 Post COVID-19 Economic Outlook

Projections		2019	2020	2021	2022	2023	2024	2025
		%	%	%	%	%	%	%
IMF	2017.04	6.5	6.5	6.5	6.5			
	2020.04	6.3	2.0	4.6				
	2020.10	7.0	1.9	3.6	6.1	6.5	6.6	6.7
	2021.04	7.0	1.0	2.7	4.7	5.1	5.5	5.5
AfDB	2020.07	6.8	3.6	5.5				
	2020.12	6.8	2.1	4.1	5.8			
IEEJ	2018.10	6.5	6.5	6.5	6.5	6.5	6.5	6.5
	2021.08	7.0	1.0	2.7	4.7	5.1	5.5	5.5

Source: African Development Bank, IMF, Study Team

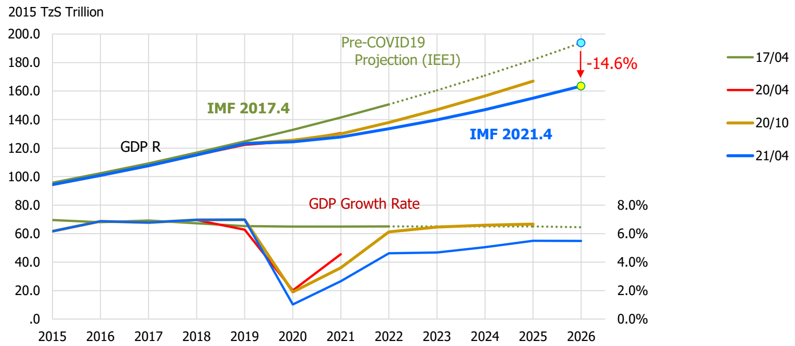


Figure 5.2-1 Post COVID-19 Economic Outlook

In 2020 the world energy market was doubly affected by the COVID-19 and overproduction of shale oil and gas. However, energy prices rebounded in the first quarter of 2021 as shown in Figure 5.2.2 and 5.2-3. Oil price remained firm and natural gas price further jumped up in the second and third quarters. These may have been caused by the cold winter in 2021 and decreased gas stocks in Europe, shrinking investment in US shale oil and gas under the Baiden administration, troubles on LNG plants and delay in start-up of the Nord Stream 2.

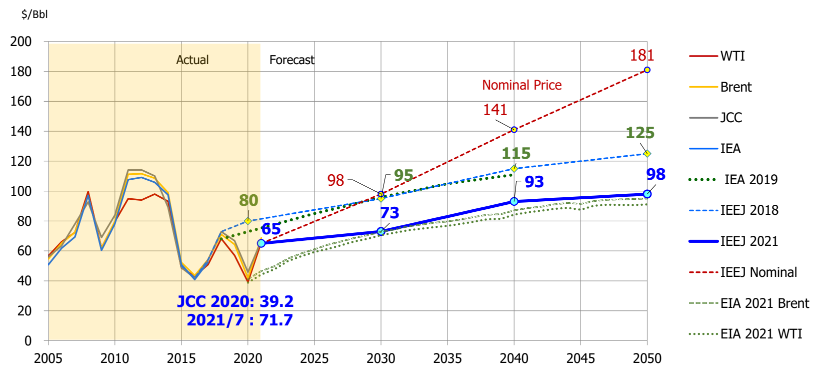


Figure 5.2-2 Oil Price Scenario

As discussed in Section 2.4, we assume that the world oil price in real term will rise only slowly from the present level while the nominal price may reach $100 per barrel by 2030. As the world oil market looks firm at present, analysts are still caotic in setting their views. The oil price will be affected by how fast the pandemic would be controlled and how strongly the investment in the US shale oil production would recover.

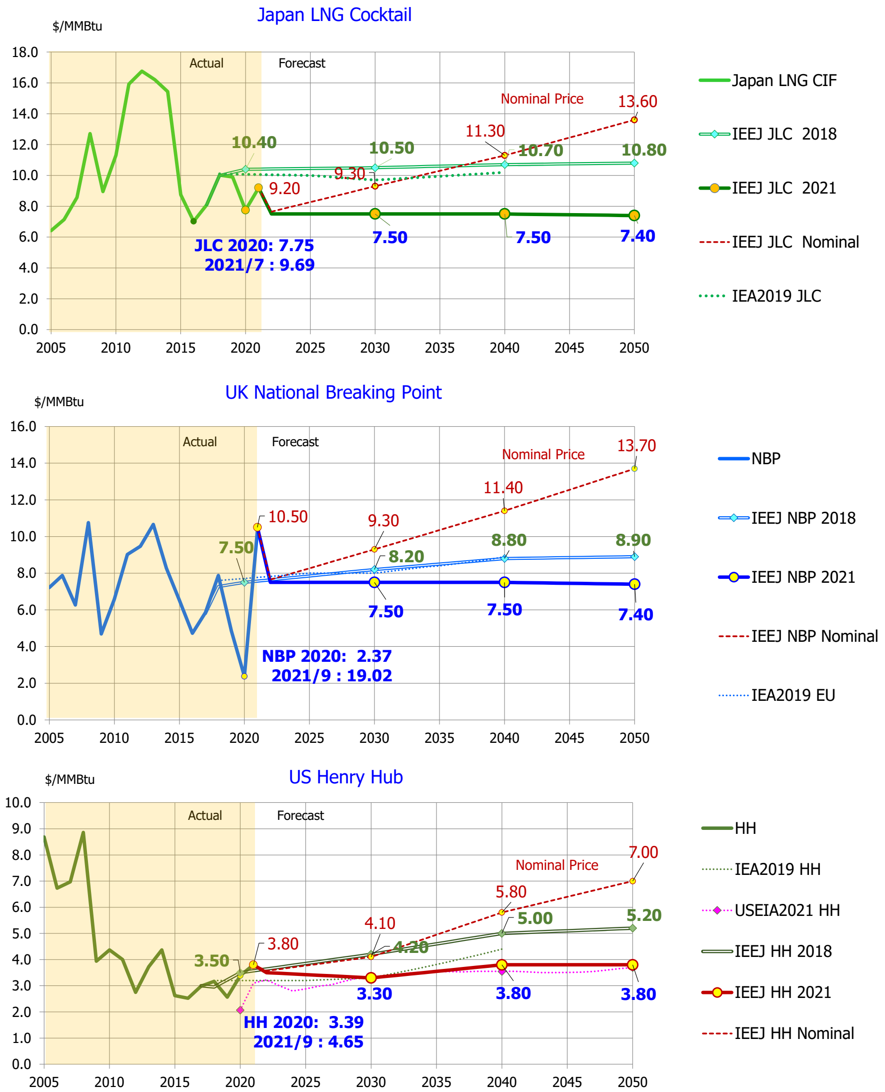


Figure 5.2-3 Gas Price Scenario

Despite the present boiling market, natural gas prices are assumed to remain more stagnant in the long run. Transitory events such as lower inventory caused by cold winter and LNG plant troubles may cease to effect eventually. Market will be dominated by the significant amount of incremental natural gas supply associated with the shale oil production in the United States and coming from several Russian giant projects. In the United States, new gas pipelines are built connecting the Eagleford basin and other production points to the Mexican Gulf coast to feed the gas for LNG export plants, but still a significant amount of gas is being flared at the well site. Russia is poised to increase natural gas export via the Nord Stream-2 and Turkstream piepelines and new LNG plants in the Yamal Pennisula. Qatar has decided to expand its LNG capacity to remain the world biggest producer. Combined with the accelerated shift to renewable energies, the European gas market may continue to be a severe battle field for gas suppliers.

As a result of the expanding price difference with oil products, in addition to coal to gas shifts under environmental concerns, energy shift to natural gas may accelerate in the world. On the other hand, natural gas is fossil fuel and is not allowed today as an exception in the debate of Net Zero society. Renewables may penetrate much faster than expected. These elements should be observed carefully. All in all, we assume that natural gas price will remain at the present level in the long run while its nominal price will go up constantly.

5.2.2 Post COVID-19 Energy Outlook[34]

For projection of the energy demand, basically the same energy development scenarios are applied as explained in the foregoing section. Then, due to slow down of the economic activities, energy demand growth becomes slower in 2020 onwards until the economy returns to the baseline scenario in 2023.

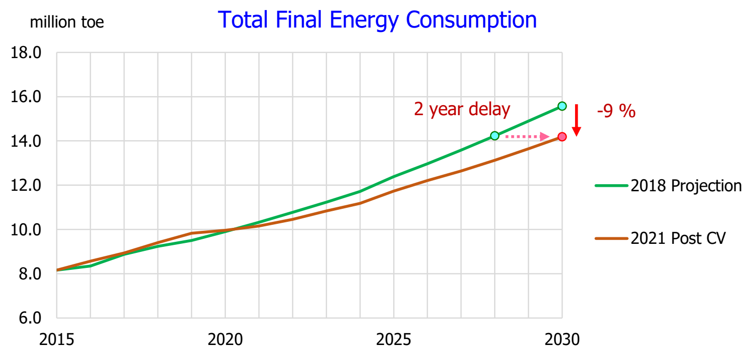


Figure 5.2-4 Energy Outlook: Pre- and Post-COVID-19

Compared with the pre-COVID-19 projection, energy demand in 2030 will be about 9% lower or 2 years behind in the post-COVID-19 projection. However, applying the same development

34 In view of the discussion in Appendix D that reliable energy data is not available for Tanzania, Ministry of Energy has initiated activities in 2019 to establish the national energy data jointly with National Bureau of Statistics. At the time of this review, however, the new energy data set was not available. Under the circumstance, although the IEA statistics is tricky and questionable, we use it in principle with similar amendments as developed in Appendix D.

In the 2021 IEA statistics compared with its 2018 version, primary solid biomass consumption in the industrial sector is reduced by 60%, but it still looks too high. No fuel consumption is reported for the commercial/public sector, which is not realistic. At a glance, meals are served at restaurants, hotels, schools and hospitals. High consumption of traditional fuel is reported for the residential sector though the estimates are reduced by 20-30%. Consumption of gasoline and diesel is reported to be stagnant since 2014 despite rapid increase in vehicle ownership. We hope more realistic energy data will be established with efforts of the Ministry.

scenarios, there would be no material changes in the basic energy trend. It should be noted that these projections do not include rise of gas-chemical industries as discussed in the Natural Gas Utilisation Master Plan nor introduction of natural gas vehicles discussed in this report. Once these policies are put in the implementation list, the long term energy outlook will change to a substantially different picture.

These projections are compared in the Table 5.2-2. Slower economic growth may delay industrialisation and modernisation of the economy. The total energy consumption will be smaller in the post-COVID world and energy shifting will be slower switching from traditional fuels such as primary biomass and charcoal. Theoretcially speaking, electricity demand may be affected most among the energy sources. Nevertheless, the baseline trend to introduce modern, convenient and clean energy sources such as gaseous fuel and electricity will continue. With strong social request, slowdown of modernisation might be more subtle.

Table 5.2-2 Comparison of Pre- and Post-COVID-19 Energy Outlook: by Sector

	Industry	Transport	Commercial /Public	Residential	Agri. /FF/Others	Non-Energy	Total
Pre-COVID	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe
2020	1,441	2,894	850	4,750	27	62	10,024
2030	2,501	5,337	1,472	6,106	56	114	15,585
2040	3,870	8,992	2,484	8,362	103	207	24,018
2050	5,535	13,634	3,936	12,541	181	357	36,184
Post-COVID							
2020	1,407	2,836	812	4,817	26	62	9,960
2030	2,208	4,736	1,263	5,839	43	98	14,188
2040	3,365	8,521	2,036	7,453	78	170	21,624
2050	4,803	14,629	3,269	10,348	139	290	33,477
Change	%	%	%	%	%	%	%
2020	-2.3	-2.0	-4.5	1.4	-3.3	-1.1	-0.6
2030	-11.7	-11.3	-14.2	-4.4	-22.5	-13.7	-9.0
2040	-13.0	-5.2	-18.0	-10.9	-23.7	-17.9	-10.0
2050	-13.2	7.3	-17.0	-17.5	-23.2	-18.8	-7.5

Table 5.2-3 Comparison of Pre- and Post-COVID-19 Energy Outlook: by Energy Source

	Coal	Natural Gas	LPG	Oil	Primary Biofuels	Charcoal	Combustible Fuel Total	Electricity	Solar	Heat	Total
Pre-COVID	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe
2020	427	201	220	3,261	2,904	1,947	8,960	964	100	0	10,024
2030	793	525	838	5,820	2,516	2,375	12,866	2,346	373	0	15,585
2040	1,160	943	2,952	9,633	1,776	1,500	17,963	5,374	680	0	24,018
2050	1,458	1,764	4,734	14,362	669	1,222	24,209	11,018	957	0	36,184
Post-COVID											
2020	463	191	169	3,206	2,962	1,961	8,951	908	100	0	9,960
2030	773	485	580	5,197	2,732	2,269	12,035	1,854	299	0	14,188
2040	1,100	889	2,467	9,170	2,016	1,393	17,035	4,074	514	0	21,624
2050	1,374	1,739	4,173	15,447	642	1,147	24,523	8,244	711	0	33,477
Change	%	%	%	%	%	%	%	%	%	%	%
2020	8.3	-5.0	-23.0	-1.7	2.0	0.7	-0.1	-5.8	-0.2	-	-0.6
2030	-2.5	-7.5	-30.8	-10.7	8.6	-4.5	-6.5	-21.0	-19.9	-	-9.0
2040	-5.2	-5.7	-16.4	-4.8	13.5	-7.2	-5.2	-24.2	-24.4	-	-10.0
2050	-5.7	-1.4	-11.8	7.6	-4.1	-6.1	1.3	-25.2	-25.7	-	-7.5

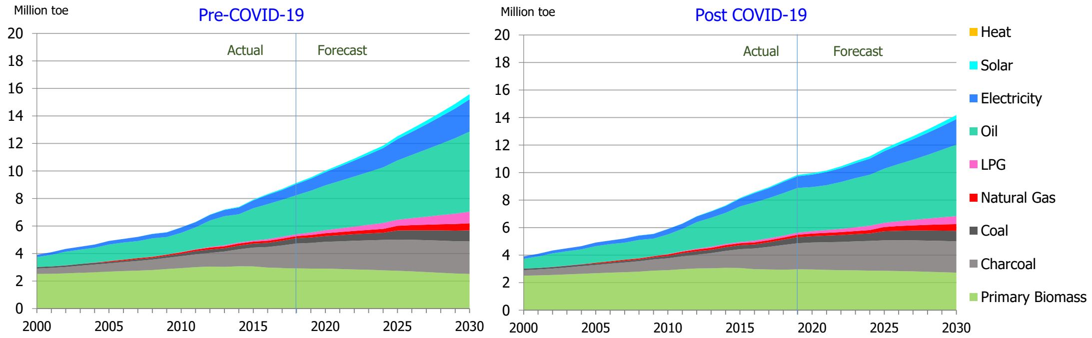


Figure 5.2-5 Comparison of Near Term Energy Outlook

Under the updated scenario, the final energy consumption of Tanzania will grow from 9,960 ktoe in 2020 to 14,188 ktoe in 2030, 21,624 ktoe in 2040 and 33,477 ktoe in 2050. Consumption of traditional fuels remain high during the 2020s but will shift to modern energies such as oil, gas and electricity after 2030 as shown in Table 5.2-4.

Table 5.2-4 Total Final Energy Demand by Energy Source: Post-COVID-19

	Actual		Forecast				Average Growth Rate					
	2000	2015	2020	2030	2040	2050	2000→ 2015	2015→ 2020	2020→ 2030	2030→ 2040	2040→ 2050	2020→ 2050
	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%
Coal	109	294	463	773	1,100	1,374	6.8	9.5	5.3	3.6	2.2	3.7
Natural Gas	0	138	191	485	889	1,739		6.6	9.8	6.3	6.9	7.6
LPG	3	80	169	580	2,467	4,173	24.5	16.2	13.1	15.6	5.4	11.3
Oil	721	2,594	3,206	5,197	9,170	15,447	8.9	4.3	4.9	5.8	5.4	5.4
Primary Biomass	2,515	3,072	2,962	2,732	2,016	642	1.3	-0.7	-0.8	-3.0	-10.8	-5.0
Charcoal	398	1,364	1,961	2,269	1,393	1,147	8.6	7.5	1.5	-4.8	-1.9	-1.8
Combustible Fuel Total	3,746	7,543	8,951	12,035	17,035	24,523	4.8	3.5	3.0	3.5	3.7	3.4
Electricity	162	567	908	1,854	4,074	8,244	8.7	9.9	7.4	8.2	7.3	7.6
Solar	0	53	100	299	514	711		13.7	11.5	5.6	3.3	6.7
Electricity total	162	620	1,008	2,153	4,589	8,954	9.4	10.2	7.9	7.9	6.9	7.6
(GWh)	1,885	7,211	11,726	25,032	53,356	104,120	9.4	10.2				7.6
Heat	0	0	0	0	0	0						
Total	3,908	8,163	9,960	14,188	21,624	33,477	5.0	4.1	3.6	4.3	4.5	4.1
(Composition)												
Coal	2.8	3.6	4.6	5.4	5.1	4.1						
Natural Gas	0.0	1.7	1.9	3.4	4.1	5.2						
LPG	0.1	1.0	1.7	4.1	11.4	12.5						
Oil	18.4	31.8	32.2	36.6	42.4	46.1						
Primary Biomass	64.3	37.6	29.7	19.3	9.3	1.9						
Charcoal	10.2	16.7	19.7	16.0	6.4	3.4						
Combustible Fuel Total	95.9	92.4	89.9	84.8	78.8	73.3						
Electricity	4.1	7.0	9.1	13.1	18.8	24.6						
Solar	0.0	0.6	1.0	2.1	2.4	2.1						
Heat	0.0	0.0	0.0	0.0	0.0	0.0						
Total	100.0	100.0	100.0	100.0	100.0	100.0						

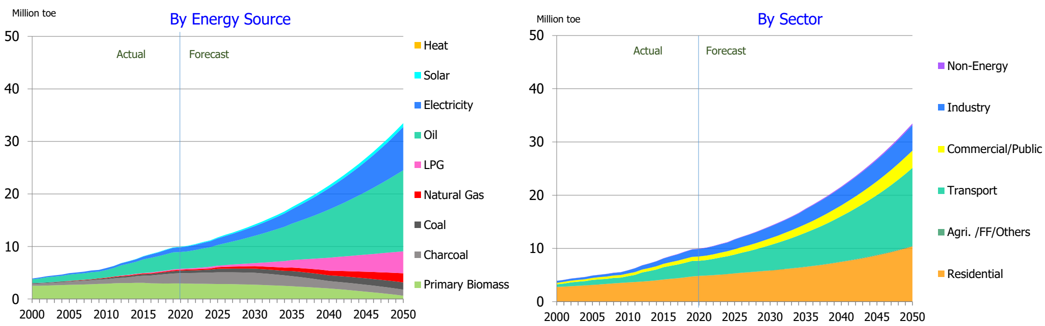


Figure 5.2-6 Total Final Energy Demand: Post-COVID-19

Among the sectors, energy consumption for transport will grow fast followed by the commercial/public sector and industry. Consumption of combustible fuel at the residential sector remains low, this is because the traditional fuel such as firewood and charcoal will be replaced with cleaner and more efficient gas fuel (natural gas and LPG) resulting in a mere 7 % increase between 2020 and 2050. On the other hand, electricity consumption of the residential sector will grow fast to modernise the daily life at an average annual growth rate of 8.8%: it expands 12.6 times between 2020 and 2050.

Growth of motor vehicles at a high speed will invite expansion of petroleum products at an explosive pace: oil consumption of the sector will increase 5.2 fold between 2020 and 2050. This will incur huge amunt of foreign currency outflow for import of them and would threat the country's economic growth. To cope with this, introduction of natural gas vehicles (NGVs) needs to be considered as discussed later. Although this requires robust planning for establishment of comprehensive energy/transport policy under extensive collaboration of relevant authorities, it is expected to bring about a great benefit for the country.

Table 5.2-5 Total Final Energy Demand by Sector: Post-COVID-19

	Actual		Forecast				Average Growth Rate					
	2000	2015	2020	2030	2040	2050	2000→ 2015	2015→ 2020	2020→ 2030	2030→ 2040	2040→ 2050	2020→ 2050
	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%
Industry	369	1,004	1,407	2,208	3,365	4,803	6.9	7.0	4.6	4.3	3.6	4.2
Transport	479	2,307	2,836	4,736	8,521	14,629	11.0	4.2	5.3	6.0	5.6	5.6
Commercial/Public	287	648	812	1,263	2,036	3,269	5.6	4.6	4.5	4.9	4.8	4.8
Residential	2,733	4,135	4,817	5,839	7,453	10,348	2.8	3.1	1.9	2.5	3.3	2.6
Agri. /FF/Others	22	22	26	43	78	139	0.0	3.2	5.3	6.1	5.9	5.8
Non-Energy	17	47	62	98	170	290	7.0	5.6	4.8	5.6	5.5	5.3
Total	3,908	8,163	9,960	14,188	21,624	33,477	5.0	4.1	3.6	4.3	4.5	4.1
(Composition)												
Industry	9.5	12.3	14.1	15.6	15.6	14.3						
Transport	12.3	28.3	28.5	33.4	39.4	43.7						
Commercial/Public	7.4	7.9	8.2	8.9	9.4	9.8						
Residential	69.9	50.7	48.4	41.2	34.5	30.9						
Agri. /FF/Others	0.6	0.3	0.3	0.3	0.4	0.4						
Non-Energy	0.4	0.6	0.6	0.7	0.8	0.9						
Total	100.0	100.0	100.0	100.0	100.0	100.0						

Modern civilisation has grown with increase of energy consumption that enables indusrialisation and higher quality of life. Given that, economic growth would not be possible only with traditional fuels such as firewood and charcoal. On the other hand, use of modern energy such as oil, gas and electricity requires extensive development of supply and utilisation infrastructure. For example, the natural gas demand is projected assuming that city gas supply will start in 2025 at 50 kt a year and expand at annual 10%, while this is just a hypothetical projection. Unless proper natural gas supply system is developed, such potential demand would simply cause increase of LPG import. In Tanzania, energy demand is currently small and markets are not densely concentrated. Therefore, supply infrastructure suitable to accommodate such market should be considered to utilise the indigenous natural gas as expected such as virtual gas pipeline system and LNG corridors as discussed later.

5.2.3 Final Energy Consumption by Sector

In this section, the final energy demand by sector is analysed and projected considering specific characteristics and development potentials in each sector. Demand projecion is made mainly by way of a scenario analysis because:

a. Reliable historical data is not available in Tanzania, necessitaing the use of hypothetical data as discussed in Appendix D; and
b. Tanzania is still in an early stage of economic development. In the coming decades, urbanisation and modernisation will dominate the Tanzanian society and Tanzanians will step in a world significantly different from the past. Therefore, any anaysis based on the past experience and historical data would not work meaningfully.

Under the circumstance, it is important to discuss and evaluate if the scenarios laid out below for energy development path look plausible, desiable and practicable. In this analysis, we set up projections by sector and assembled them into an overall outlook as explained above.

1) Industrial Sector

The industrial sector is divided into three sub-secors, namely, steel, cement and general industires.

At present, there are several steel plants processing imported coils and other materials. They are classified as general industry as their energy consumption patterns are not so peculiar like at typical steel mills producing raw steel by blast furnaces or electric furnaces. We assume that a 330,000 tpa of Sponge Iron Plant with a 45 MW captive power plant will be built in Liganga and start opertion in 2025. Its second plant may start 10 years later.

Cement industry will play an important role during the construction stage of the Tanzanian economy for the coming decades. Cement plants situated alongside the existing gas pipeline will be fueld by natural gas, while others may mainly use coal.

For the general industries, we boldly assumed in Appendix D that the primary biomass and charcoal consumption in the industrial sector were 77 ktoe and 24ktoe in 2016, respectively, before energy efficiency adjustment. This reflects the outcome of the Regional Energy Demand Survey: it was observed that consumption of primary biomass and charcoal corresponded to about 10% and 5% of fossil fuel consumption. It includes 250 tonnes per month of bagasse consumption at a sugar plant in Moshi. We apply these ratios to calculate firewood and charcoal consumption and add one paper mill operating in Iringa with a production capacity of 60,000 tpa, which may use fuel of 20 ktoe a year. No other large plants using biomass are identified. A quantity of 100 ktoe of biomass and charcoal combined may sufficiently cover the nation's industrial biomass consumption at small works such as blacksmiths and bakeries.

Consequently, industrial fuel consumption of Tanzania is estimated to be 17kg oil equivalent per capita. This is roughly 1/3 of that of the Philippines, while per capita GDP of Tanzania was about 30% of that of the Philippines. The total energy consumption including other fuels and electricity is projected assuming that energy intensity will improve along with development of the manufacturing sector. As the industrial sector modernisation progresses, primary biomass will reduce its share and will be replaced with electricity and modern energies. As domestic natural gas is available while petroleum products are imported, natural gas will play an important role in fueling the industrialisation. In the areas remote from the gas pipeline, LPG will dominate as fuel for light indutries.

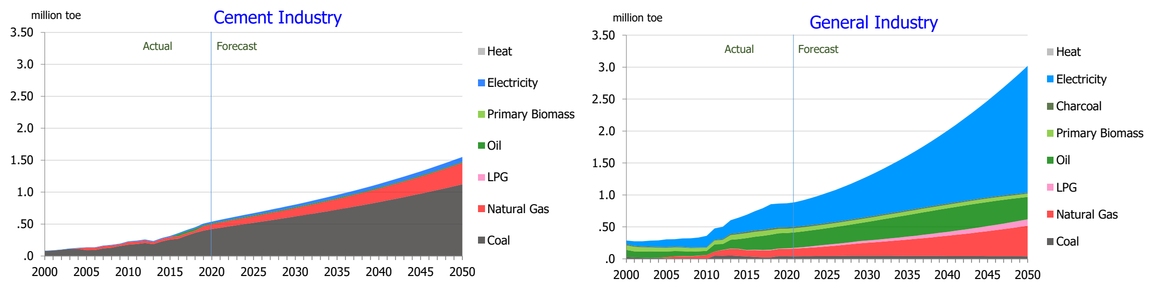


Figure 5.2-7 Energy Demand of Cement Industry and General Industry

Outcomes of the industrial sector energy demand projection are shown in Figure 5.2-8 and Table 5.2-6. This projection does not include construction of specific gas-based industry such as fertiliser or methanol plants. Energy and feedstock requirement by such industry should be added on top of this projection once their construction projects are confirmed.

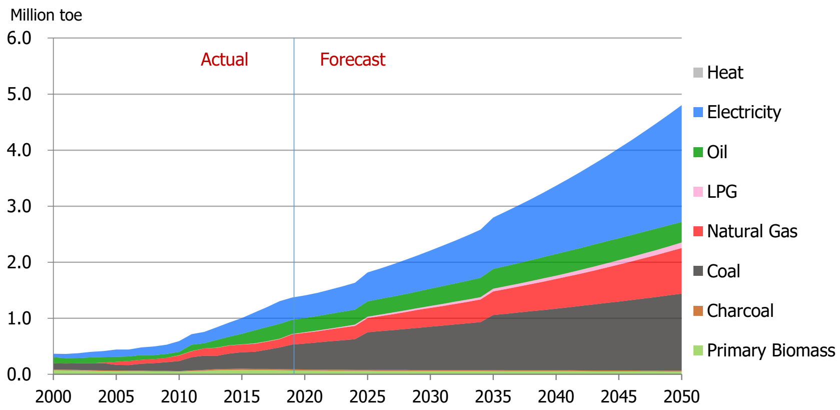


Figure 5.2-8 Final Energy Demand: Industrial sector

The industrial sector energy consumption will icrease rapidly from 1,407 ktoe in 2020 to 2,208 ktoe in 2030 and double again to 4,803 ktoe in 2050. Use of firewood may remain in a small quantity in countryside, while industrialisation will be driven mainly by natural gas, coal and electricity. To suffice the fast expanding energy consumption for indutrialisation, construction of energy supply infrastructure should be considered as a key enabler.

Table 5.2-6 Final Energy Demand: Industry Sector

	Actual		Forecast				Average Groth Rate					
	2000	2015	2020	2030	2040	2050	2000→ 2015	2015→ 2020	2020→ 2030	2030→ 2040	2040→ 2050	2020→ 2050
	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%
Coal	109	294	463	773	1,100	1,374	5.7	25.3	5.3	3.6	2.2	4.9
Natural Gas	0	138	190	334	529	813		17.4	5.8	4.7	4.4	5.7
LPG	0	4	9	35	60	100	20.0	50.8	14.4	5.6	5.2	10.6
Oil	109	186	256	306	385	366	3.0	17.2	1.8	2.3	-0.5	2.1
Primary Biomass	73	79	67	60	56	50	0.4	-7.5	-1.2	-0.7	-1.0	-1.4
Charcoal	15	21	21	18	17	15	1.9	-1.8	-1.2	-0.7	-1.0	-1.0
Combustible Fuel Total	307	723	1,006	1,527	2,147	2,719	4.9	18.0	4.3	3.5	2.4	4.2
Electricity	63	281	402	681	1,218	2,084	8.7	19.6	5.4	6.0	5.5	6.5
Heat	0	0	0	0	0	0						
Total	369	1,004	1,407	2,208	3,365	4,803	5.7	18.4	4.6	4.3	3.6	5.0
(Composition)												
Coal	29.5	29.3	32.9	35.0	32.7	28.6						
Natural Gas	0.0	13.8	13.5	15.1	15.7	16.9						
LPG	0.0	0.4	0.6	1.6	1.8	2.1						
Oil	29.5	18.5	18.2	13.9	11.4	7.6						
Primary Biomass	19.8	7.9	4.8	2.7	1.7	1.0						
Combustible Fuel Total	83.0	72.0	71.5	69.1	63.8	56.6						
Electricity	17.0	28.0	28.5	30.9	36.2	43.4						
Heat	0.0	0.0	0.0	0.0	0.0	0.0						
Total	100.0	100.0	100.0	100.0	100.0	100.0						

2) Transport Sector

Road transport dominates in Tanzania. Although there are minor services by air, rail and ships, statistics are not available on their energy consumption. In the following discussion, these other modes of transport will be disregarded for the time being while proper statistics should be collected and organised in due course.

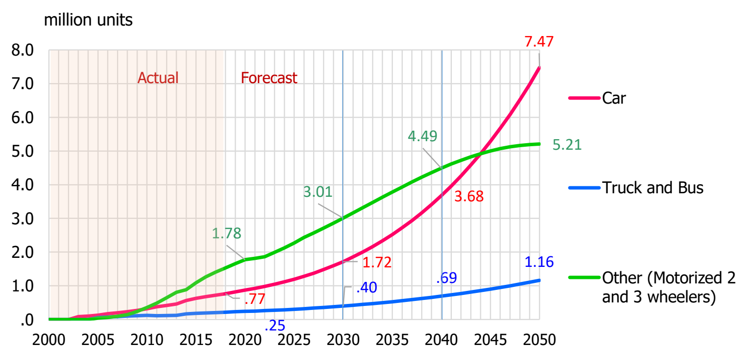


Figure 5.2-9 Number of Road Vehicles

The number of motor vehicles is projected assuming that mortorisation will progress as economy grows and disposable income increases. Motorcycles will penetrate rapidly at first and passenger vehicles will follow and eventually overtake motorcycles before 2050. Since this projection is made on the data of small and very early stage of vehicle penetration, it involves a lot of uncertainty. The penetration curve may change upward or downward significantly reflecting the mode of modernisation people would adopt in the course of changing their life style as well as development of other modern transport system such as railway and air services.

Assuming that fuel mileage will improve steadily, fuel demand for road vehicles is projected as shown in Figure 5.2-10 and Table 5.2-7.

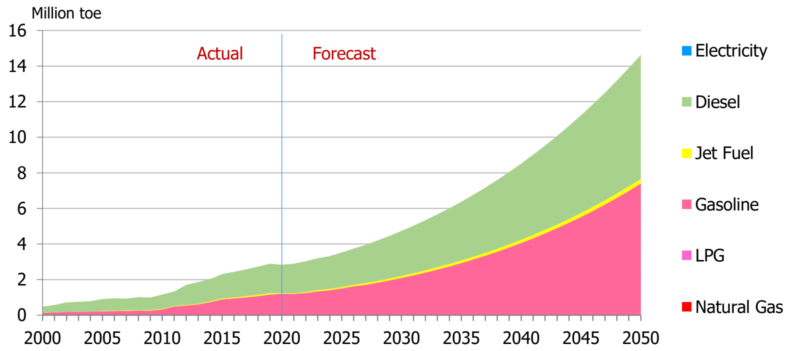


Figure 5.2-10 Fuel Demand: Transport Sector

While a small number of CNG vehicles are used in an experimental project in Dar es Salaam, wider use of them is not considered here. However, gas-fueled vehicles are widely used in the world and their numbers are increasing. CNG is used for light duty vehicles and LNG for heavy duty vehicles such as trucks and buses. To implement a gas-based transport program, certain number of vehicles must be present to provide the base demand to justify construction of the gas supply system. Once such coherent policy is established, gasification of motor vehicles may be initiated in Tanzania.

The projection here may provide a basic idea to consider such energy-transport policy. Fuel demand for road transport was 2,297 ktoe in 2016. It will more than double by 2030, and will exceed 10 million toe before 2050. Although rapid improvement of fuel mileage is assumed, i.e. 20% for the next decade and 10% for the succeeding decades, the growth in fuel demand will accelerate. After populerisation of general home appliances, although its timing is debatable, mortorisation may progresses faster than the income growth.

Table 5.2-7 Fuel Demand: Transport Sector

	Actual		Forecast				Average Groth Rate					
	2000	2015	2020	2030	2040	2050	2000→ 2015	2015→ 2020	2020→ 2030	2030→ 2040	2040→ 2050	2020→ 2050
	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%
Natural Gas	0	0	0	0	0	0						
LPG	0	0	0	0	0	0						
Gasoline	129	885	1,205	2,092	4,056	7,398	13.7	6.4	5.7	6.8	6.2	6.2
Jet Fuel	0	51	26	108	181	254		-12.4	15.2	5.3	3.4	7.8
Diesel	350	1,371	1,604	2,536	4,284	6,977	9.5	3.2	4.7	5.4	5.0	5.0
Electricity	0	0	0	0	0	0						
Total	479	2,307	2,836	4,736	8,521	14,629	11.0	4.2	5.3	6.0	5.6	5.6
(Composition)												
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0						
LPG	0.0	0.0	0.0	0.0	0.0	0.0						
Gasoline	26.9	38.4	42.5	44.2	47.6	50.6						
Jet Fuel	0.0	2.2	0.9	2.3	2.1	1.7						
Diesel	73.1	59.4	56.6	53.5	50.3	47.7						
Electricity	0.0	0.0	0.0	0.0	0.0	0.0						
Total	100.0	100.0	100.0	100.0	100.0	100.0						

3) Commercial and Services Sector

Commercial and services sector energy consumption is not well grasped in Tanzania. Generally, they are used for lighting, cooking, hot water supply, space heating and airconditioning. In the previous sector, we assume the per capita fuel use of 20kg per urban resident, in view of the findings of the Regional Energy Demand Survey (REDS).

Adopting TANESCO's statistics, the nationwide electrification ratio is calculated to be 20.8% in 2016. The REDS suggests an electrification ratio of 27.4% in 2018 as an average of the selected cities. Including non-electrified rural areas, the foregoing assumption is considered to represent a reasonable national average.

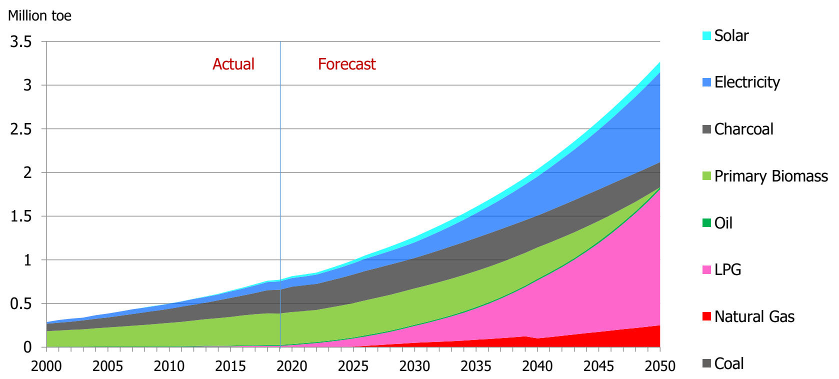


Figure 5.2-11 Final Energy Demand: Commercial and Services Sector

Since cold weather is not generally anticipated in Tanzania, fuel is used mainly for cooking in the commercial and services sector. From the Japanese experience, fuel consumption for such purpose would change only slightly as people will go out more often when income increases. Among fuel use, firewood is used widely in 2018 according to the Regional Energy Demand Survey, amounting to 50% of the total fuel consumption. However, charcoal, LPG and natural gas will penetrate fast and the use of firewood will decrease and eventurally cease. We assume that city gas supply with natural gas will start in 2025 and increase by 10% per annum; charcoal will decrease its share among fuels from 86% in 2016 to 40% in 2030 and 10% in 2050 on an energy efficiency equivalent basis. Nevertheless, the charcoal consumption volume will increase from 214 ktoe in 2016, to 289 ktoe in 2020 and continue to grow to over 350 ktoe before it starts to decline in the 2040s. LPG will be a preferred fuel to replace charcoal and firewood. If city gas supply systems were developed extensively, more natural gas will be used in place of LPG.

Modernisation of offices and commercial facilities will definitely reqire electricity. It is assumed that as economic growth and urbanisation progress, demand for electricity grows fast and its growing speed will accelerate until electrification reaches a certain level. The sector's electricity consumption will grow from 100 ktoe in 2020 to 178 ktoe in 2030, 449 ktoe in 2040 and 1,033 ktoe in 2050, with an overall growth rate being 8.1% per annum.

Since solar irradiation is abundant and there are a number of tourist facilities in rural areas, solar PV will be widely used. Its share in the electricity consumption is estimated to be one third of the commercial sector electricity consumption in 2016. Use of solar PV will continue to increase, while its share of the toal electricity consumption will decline eventually to 10% as the grid electricity suppuly will be developed.

Overall energy consumption of the commercial and services sector is estimated to be 812 ktoe in 2020, and 85% of which was fuel. Energy consumption in the sector will continue to grow fast at over 4.8% per annum during the projection period and reach 1,263 ktoe in 2030, 2,036 ktoe in 2040 and eventually 3,269 ktoe in 2050. The share of electricity expands much faster increasing from 14.1% in 2016 to 22.0% in 2030 and 31.6% in 2050.

Table 5.2-8 Final Energy Demand: Commercial and Services Sector

	Actual		Forecast				Average Groth Rate					
	2000	2015	2020	2030	2040	2050	2000→ 2015	2015→ 2020	2020→ 2030	2030→ 2040	2040→ 2050	2020→ 2050
	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%
Coal	0	0	0	0	0	0						
Natural Gas	0	0	0	50	100	250		0.0	65.9	7.2	9.6	24.9
LPG	0	8	22	193	665	1,558	24.5	22.6	24.2	13.1	8.9	15.2
Oil	3	8	12	13	16	23	7.1	8.0	0.5	2.6	3.7	2.2
Primary Biomass	179	330	368	417	360	0	4.1	2.2	1.3	-1.5	-100.0	-100.0
Charcoal	85	218	289	348	364	287	6.5	5.8	1.9	0.5	-2.4	-0.0
Combustible Fuel Total	268	564	692	1,021	1,506	2,118	5.1	4.2	4.0	4.0	3.5	3.8
Electricity	20	73	100	178	449	1,033	9.1	6.4	5.9	9.7	8.7	8.1
Solar	0	11	20	64	82	117		13.5	12.4	2.6	3.7	6.1
Electricity Total	2,000	2,015	2,020	2,030	2,040	2,050	0.0	0.0	0.0	0.0	0.0	0.0
(GWh)	2,000	2,015	2,020	2,030	2,040	2,050	0.0	0.0				0.0
Heat	0	0	0	0	0	0						
Total	287	648	812	1,263	2,036	3,269	5.6	4.6	4.5	4.9	4.8	4.8
(Composition)												
Coal	0.0	0.0	0.0	0.0	0.0	0.0						
Natural Gas	0.0	0.0	0.0	4.0	4.9	7.6						
LPG	0.1	1.2	2.7	15.3	32.7	47.7						
Oil	1.0	1.3	1.5	1.0	0.8	0.7						
Primary Biomass	62.4	50.9	45.3	33.0	17.7	0.0						
Charcoal	29.6	33.6	35.6	27.5	17.9	8.8						
Combustible Fuel Total	93.1	87.0	85.2	80.8	73.9	64.8						
Electricity	6.9	11.3	12.3	14.1	22.0	31.6						
Solar	0.0	1.6	2.4	5.0	4.0	3.6						
Electricity Total	6.9	13.0	14.8	19.2	26.1	35.2						
Heat	0.0	0.0	0.0	0.0	0.0	0.0						
Total	100.0	100.0	100.0	100.0	100.0	100.0						

4) Residentail Sector

In Tanzania there are several surveys conducted on household energy consumption for lighting and cooking, but they are not compiled in the form of consistent statistics to show national total energy consumption in this sector. Therefore, we consider a scenario with bold assumptions as structured below.

As discussed in Appendix D, we assume per capita home fuel consumption at 67 kgoe for 2016 (Figure D.1.2). This is substantially lower than the IEA's assessment of 312 kgoe which assumes a huge amount of firewood used for cooking. Then, in terms of apparent energy consumption, differences in energy use efficiency among fuels are factored; i.e. 25% for firewood with non-efficient stoves, 35% for charcoal which cannot be switched off after use, and 50% for modern fuels such as gas used with smart stoves. It is further assumed that:

a. The fuel use for cooking will remain at 25 kgoe, or at a similar level with Japan, and that for hot water estimated at 12 kgoe per capita for 2016 will increase reflecting the growth of personal consumption per capita;
b. Energy efficiency will improve by 0.5% per annum;
c. Firewood ratio is estimated at 15% for urban area and 60% for rural area in 2018, and these will decrease in urban area to 10% by 2030 and 5% by 2040, and in rural area to 40% by 2030, 20% by 2040 and 10% by 2050;
d. Charcoal ratio is estimated at 80% for urban area and 40% for rural area in 2018, and these will decrease in urban area to 30% by 2030 and 10% by 2040 while in rural area increase to 50% by 2030 before decreasing to 30% by 2040 and 20% by 2050;
e. The rest will be suppllied by natural gas and LPG, where city gas supply will start in 2025 at 50 ktoe and thereafter increase by 10% per annum.

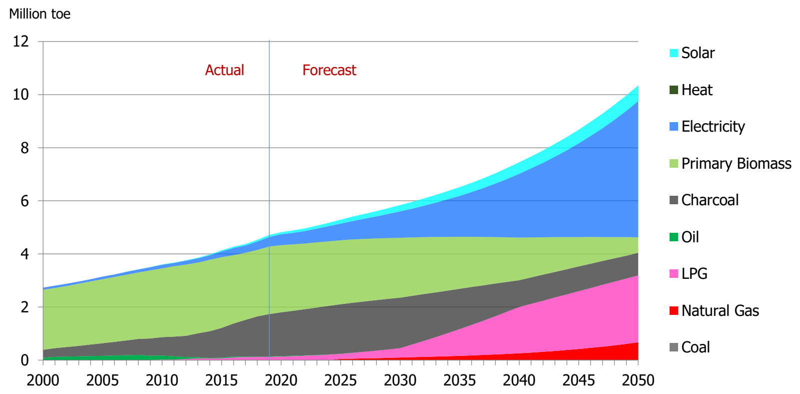


Figure 5.2-12 Final Energy Demand: Residential Sector

According to the Energy Access Situation Survey 2016 (EASS 2016), the electricity grid connected ratio was 65.3% in urban ares, 16.9% in rural ares, and 32.8% for the mainland total. We assume this ratio will go up as follows:

a. Urban: 70% by 2020, 90% by 2030 and 100% by 2040:
b. Rural: 20% by 2020, 50% by 2030, 80% by 2040 and 100% by 2050.

Light and power at home will be supplied from the grid as well as solar PV. Rechargeable batteries are used widely in the country. However, they are presumably recharged either from the grid or solar PV and therefore not considered as a separate energy source. According to the EASS 2016, the share of solar and other sources for lighting was 3.6% for urban areas and 65.4% for rural areas in 2016. We assume that the ratio will evole as follows:

a. Urban: it will slightly decline to 2.5% by 2050 and remain there as urban residents may prefer envronment-friendly energy source to some extent;
b. Rural: it decreases to 70% by 2020, 40% by 2030, 30% by 2040 and 20% by 2050.

It is also assumed that the elctricity demand will grow fast in the early stage of economic development with the value of elasticity over the per capita consumption expenditure growth accelerating to 1.3, as observed in developed countries during their early electrification and modernisation days. The demand growth will gradually slow down in the later period when home appliances are popularized among households, though in absolute terms the annual incremental volume will rather increase. Overall electricity consumption will grow from 406 ktoe in 2020 to 994 ktoe in 2030, 2,407 ktoe in 2040 and 5,126 ktoe in 2050; or 13-fold during the projection period at an average annual growth rate of 8.8 %.

An overall projection for the energy requirement developed based on the above assumptions is given in Figure 5.2-12 and Table 5.2-9. The household sector energy consumption will increase from 4,817 ktoe in 2020 to 5,839 ktoe in 2030 and 10,348 ktoe in 2050. As electrification progresses, increase of energy consumption, in particular, electricity will accelerate. This will be general phnomenon observed in many countries during pupularisation of home appliances. Among fuels, use of firewood decreases constantly, while use of charcoal will increase for some period due to population movement to urban areas without sufficient modern energy supply, and start to decline only around 2030 thanks to penetration of LPG and city gas.

Table 5.2-9 Final Energy Demand: Residential Sector

	Actual		Forecast				Average Groth Rate					
	2000	2015	2020	2030	2040	2050	2000→ 2015	2015→ 2020	2020→ 2030	2030→ 2040	2040→ 2050	2020→ 2050
	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%
Coal	0	0	0	0	0	0						
Natural Gas	0	0	0	101	261	677				10.0	10.0	
LPG	3	68	138	352	1,742	2,516	24.5	15.2	9.8	17.4	3.7	10.2
Oil	91	24	15	0	0	0	-8.5	-8.8	-100.0			-100.0
Primary Biomass	2,262	2,663	2,526	2,255	1,600	592	1.1	-1.1	-1.1	-3.4	-9.5	-4.7
Charcoal	298	1,125	1,651	1,903	1,011	845	9.3	8.0	1.4	-6.1	-1.8	-2.2
Combustible Fuel Total	2,654	3,880	4,330	4,610	4,614	4,629	2.6	2.2	0.6	0.0	0.0	0.2
Electricity	79	213	406	994	2,407	5,126	6.8	13.8	9.4	9.3	7.9	8.8
Solar	0	42	80	235	432	593		13.8	11.3	6.3	3.2	6.9
Electricity Total	2,000	2,015	2,020	2,030	2,040	2,050	0.0	0.0	0.0	0.0	0.0	0.0
(GWh)	2,000	2,015	2,020	2,030	2,040	2,050	0.0	0.0				0.0
Heat	0	0	0	0	0	0						
Total	3,605	4,135	4,817	5,839	7,453	10,348	0.9	3.1	1.9	2.5	3.3	2.6
(Composition)												
Coal	0.0	0.0	0.0	0.0	0.0	0.0						
Natural Gas	0.0	0.0	0.0	1.7	3.5	6.5						
LPG	0.1	1.6	2.9	6.0	23.4	24.3						
Oil	2.5	0.6	0.3	0.0	0.0	0.0						
Primary Biomass	62.8	64.4	52.4	38.6	21.5	5.7						
Charcoal	8.3	27.2	34.3	32.6	13.6	8.2						
Combustible Fuel Total	73.6	93.8	89.9	78.9	61.9	44.7						
Electricity	2.2	5.2	8.4	17.0	32.3	49.5						
Solar	0.0	1.0	1.7	4.0	5.8	5.7						
Electricity Total	2.2	6.2	10.1	21.1	38.1	55.3						
Heat	0.0	0.0	0.0	0.0	0.0	0.0						
Total	100.0	100.0	100.0	100.0	100.0	100.0						

5) Others

There are sometimes mistreatments in energy statistics on the agroforestry sector, and the IEA statistics may have made it for Tanzania as it assumes 16.5kg oil equivalent primary biomass consumption per person (calculated on a national population basis) throughout the data period since 2000. It may be true that a certain amount of woods, grasses and agriculture residues is burnt every year in countryside. However, they should be rather deemed as disposal of wastes unless they are specifically used as energy for agroforestry activities. Compost and ash are utilized as fertilisers, but not as energy. At least, urban population should not be considered as a basis for such estimation. Thus, we dismiss all figures listed in the IEA statistics as consumption of primary biomass and instead pick up the small quantity of oil products that may have been used for driving vehicles, machines and ships. These will gradually replace cattle and horses. We project these figures in line with the projection for the agriculture sector GDP as shown in Figure 5.2-13.

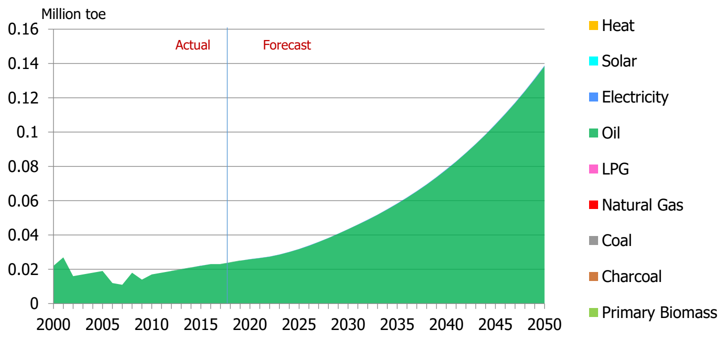


Figure 5.2-13 Final Energy Demand: Agriculture and Others

5.3 Macro Analysis on Regional Energy Demand

Construction of nationwide gas pipeline system is proposed by the final draft of the NGUMP and hence the DNGPP study is implemented to formulate a plan to this end. While the national energy trend is analized in Section 5.1, it is necessary to know regional distribution of future gas demand to set out a basic picture for such plan.

The NGUMP proposes construction of the nationwide pipeline system in three phases. In the Phase-I, it plans to construct pipelines for three routes:

a. From Dar es Salaam via Dodoma through to Mwanza
b. Dar es Salaam via Tanga through to Arusha
c. Mtwara to Njombe

Figure 5.3-1 NGUMP Pipeline Plan

Considering realistic construction schedule, this Phase-I plan may be further divided into three stages to cover groups of cities as below:

Group-A: Morogoro, Dodoma, Tanga, Moshi, Arusha

Group-B: Tabora, Mwanza
Group-C: Areas along the route from Mtwara to Njombe

As the first approach, this study takes up the Phase-I Group-A cities as above. However, population is not so dense and economy is not so active to cosume high volume of energy. As construction of pipeline is proposed in the NGUMP, regional demand would be too small to justify it. In the early stage of gasification, therefore, we need to consider alternative methods to distribute gas by rail and/or truck, which concept is recently being developed as “virtual pipeline.” Its technical aspect will be discussed in Chapter 6.

As the basis to set the grand design, we analyze regional energy demand trends as follows:
Section 5.3: Macro analysis on energy demand outlook of all regions
Section 5.4: Gas demand outlook of objective regions
Section 5.5: Prospective gas demand in Phase-1 Group-A cities
Section 5.6: Prospect of natural gas supply as automotive fuel

5.3.1 Regional Economic Trends

1) Regional Population trends

Based on the national population estimation explained in the previous section, regional population is estimated taking account of the histrorical trend in each region. This projection is made in line with natural trends observed on the historical data without consideration on specific policy guidance. Population in each region is increasing at around 2.6% per year during 2016-2020. In particular, reflecting the economic development of Dar es Salaam and the shifting of the fucntion as the national capital to Dodoma, it is observed in the past trend that a large population has emigrated into these two regions, and thus we project that population in these cities will expand rapidly at 2.8% and 3.0% during 2020-2030. On the other hand, in regions where economic development is relatively advanced, for example, Mtwara Region, Arusha Region and Kilimanjaro Region, the rate of population growth will gradually slow down to 1.1% for the period from 2040 to 2050.

Next, looking at the urbanisation ratio in each region, in addition to Dar es Salaam, regions where the urbanisation ratio has already advanced as of 2016 are Pwani Region (62.1%), Mbeya Region (55.5%), Zanzibar[35] (48.9%) and Morogoro Region (41.6%). However, in the regions such as Dodoma Region (17.4%), Kagera Region (13.9%), Mara Region (13.7%) and Singida Region (13.2%) located in the western inland, economic development looks delayed due to difficult access to major infrastructure. In these regions, urbanisation ratio is low, and there is a possibility that regional disparities will further expand during the course of future economic development. As Pwani Region and Morogoro Region are located adjacent to Dar es Salaam, with a spill-over effect of Dar es Salaam's economic development, urbanisation ratios of these two

[35] Total 5 regions of Zanzibar.

regions are relatively higher than those in other regions.

Table 5.3-1 Population Projection by Region

Region	Actual	Forecast (Thousand)				Annual Average Growth Rate (%)			
	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Arusha	1,891	2,050	2,478	2,881	3,207	2.0	1.9	1.5	1.1
Dar es Salaam	5,465	6,177	8,127	10,105	11,896	3.1	2.8	2.2	1.6
Dodoma	2,265	2,587	3,475	4,384	5,220	3.4	3.0	2.4	1.8
Iringa + Njombe	1,710	1,836	2,172	2,479	2,714	1.8	1.7	1.3	0.9
Kagera	2,790	3,086	3,893	4,687	5,377	2.6	2.3	1.9	1.4
Kigoma	2,342	2,620	3,379	4,140	4,816	2.8	2.6	2.0	1.5
Kilimanjaro	1,759	1,921	2,360	2,780	3,132	2.2	2.1	1.7	1.2
Lindi	898	972	1,172	1,359	1,511	2.0	1.9	1.5	1.1
Manyara	1,618	1,817	2,360	2,907	3,397	2.9	2.7	2.1	1.6
Mara	1,924	2,126	2,675	3,213	3,680	2.5	2.3	1.9	1.4
Mbeya + Songwe	3,226	3,574	4,518	5,449	6,260	2.6	2.4	1.9	1.4
Morogoro	2,437	2,694	3,390	4,075	4,668	2.5	2.3	1.9	1.4
Mtwara	1,335	1,453	1,771	2,073	2,323	2.1	2.0	1.6	1.1
Mwanza + Geita	5,055	5,662	7,317	8,977	10,458	2.9	2.6	2.1	1.5
Pwani	1,198	1,320	1,652	1,976	2,255	2.5	2.3	1.8	1.3
Rukwa + Katavi	1,785	1,992	2,559	3,126	3,628	2.8	2.5	2.0	1.5
Ruvuma	1,499	1,653	2,072	2,483	2,837	2.5	2.3	1.8	1.3
Shinyanga + Simiyu	3,372	3,714	4,641	5,546	6,324	2.4	2.3	1.8	1.3
Singida	1,504	1,659	2,078	2,488	2,842	2.5	2.3	1.8	1.3
Tabora	2,576	2,873	3,682	4,488	5,201	2.8	2.5	2.0	1.5
Tanga	2,236	2,455	3,049	3,625	4,115	2.4	2.2	1.7	1.3
Tanzania (Mainland)	48,884	54,242	68,818	83,240	95,859	2.6	2.4	1.9	1.4
Zanzibar Total	1,467	1,643	2,121	2,600	3,026	2.9	2.6	2.1	1.5
Tanzania Total	50,351	55,885	70,939	85,840	98,886	2.6	2.4	1.9	1.4

Source: Actual data year 2016 by NBS, Tanzania.

Table 5.3-2 Urbanisation Ratio by Region

Region	Actual (%)	Projection (%)			
	2016	2020	2030	2040	2050
Arusha	38.6	41.3	48.9	54.2	58.0
Dar es Salaam	100.0	100.0	100.0	100.0	100.0
Dodoma	17.4	19.9	23.6	30.2	37.4
Iringa + Njombe	33.6	35.9	43.8	50.7	55.4
Kagera	13.9	18.9	22.3	28.1	35.2
Kigoma	28.0	30.9	38.2	46.1	52.3
Kilimanjaro	23.7	26.1	33.0	40.5	48.2
Lindi	18.1	20.2	24.2	30.9	38.2
Manyara	18.1	20.2	24.2	30.9	38.2
Mara	13.7	18.9	22.3	28.1	35.2
Mbeya + Songwe	55.5	56.9	60.4	63.6	66.4
Morogoro	41.6	44.6	51.3	55.8	59.4
Mtwara	31.8	34.4	42.2	49.5	54.6
Mwanza + Geita	38.9	42.2	49.5	54.6	58.4
Pwani	62.1	63.3	66.2	68.7	70.3
Rukwa + Katavi	35.6	38.9	46.8	52.8	56.9
Ruvuma	22.8	25.5	32.3	39.7	47.5
Shinyanga + Simiyu	15.9	19.5	23.0	29.5	36.6
Singida	13.2	17.4	21.9	27.4	34.4
Tabora	17.4	19.9	23.6	30.2	37.4
Tanga	34.2	37.4	45.4	51.8	56.1
Tanzania (Mainland)	32.3	35.2	43.0	50.1	55.0
Zanzibar Total	48.9	51.3	55.8	59.4	62.7
Tanzania Total	32.3	35.2	43.0	50.1	55.0

Source: Actual data year 2016 by NBS, Tanzania.

In the future, progress of urbanisation in these regions will greatly affect their energy demand structures for residential and commercial sectors. As more and more population moves to urban areas, shift from traditional biomass fuel to modern energy will be accelerated. If energy infrastructure is properly developed to accommodate these requirements, such as supply systems for electricity, LPG and city gas, energy use efficiency will also improve greatly.

2) Regional Economic Trend

Economic development in each region is projected based on the historical trend without consideration on specific policy initiative applying the similar process for regional population estimates. Regional economies wil be growing at the AAGR of around 6.7% during the time from 2016 to 2020, and this will slow down to around 5.8% for the period between 2040 and 2050. It is noteworthy that the total GDP of the three regions, namely, Dar es Salaam (7.8 trillion TZS, 16.6%), Mwanza Region (4.5 trillion TZS, 9.4%) and Mbeya Region (3.4 trillion TZS, 7.3%) account for 33.3% of the nation's GDP (at 2007 prices). These three regions will continue to play important roles in the future economic growth of the country.

Meanwhile, it is noted that each region develops its own development strategies reflecting respective socio-economic background.Arusha Region and Kilimanjaro Region will continue their development of service sectors pulled by further promotion of the tourism industry. Tanga Region will continue to devleop as a port city and enhance its industry and trade market. Morogoro will challenge upgrading of its agriculture and industrial sectors taking advantage of its strategic position as a backyard support center for Dar es Salaam. These regions will also make important contributions to development of the Tanzanian economy.

Table 5.3-3 GDP Projection by Region (Real GDP, 2007 price)

Region	Actual (Billion TZS)		Projection (Billion TZS)				Annual Average Growth Rate (%)				
	2010	2016	2020	2030	2040	2050	2016/ 2010	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Arusha	1,508	2,163	2,837	5,439	10,082	18,113	6.2	7.0	6.7	6.4	6.0
Dar es Salaam	5,200	7,822	10,503	21,245	41,342	77,625	7.0	7.6	7.3	6.9	6.5
Dodoma	982	1,344	1,899	4,270	9,025	18,113	5.4	9.0	8.4	7.8	7.2
Iringa + Njombe	1,631	2,261	2,831	4,803	7,803	12,138	5.6	5.8	5.4	5.0	4.5
Kagera	1,208	1,818	2,285	3,920	6,456	10,214	7.1	5.9	5.5	5.1	4.7
Kigoma	868	1,334	1,684	2,921	4,872	7,827	7.4	6.0	5.7	5.3	4.9
Kilimanjaro	1,378	2,043	2,570	4,414	7,282	11,541	6.8	5.9	5.6	5.1	4.7
Lindi	596	902	1,187	2,295	4,288	7,763	7.2	7.1	6.8	6.5	6.1
Manyara	1,027	1,537	1,966	3,537	6,149	10,350	6.9	6.4	6.0	5.7	5.3
Mara	1,122	1,689	2,089	3,418	5,303	7,763	7.1	5.5	5.0	4.5	3.9
Mbeya + Songwe	2,277	3,423	4,436	8,246	14,833	25,875	7.0	6.7	6.4	6.0	5.7
Morogoro	1,508	2,209	2,890	5,504	10,141	18,113	6.6	7.0	6.7	6.3	6.0
Mtwara	888	1,242	1,577	2,781	4,728	7,763	5.8	6.2	5.8	5.4	5.1
Mwanza + Geita	2,834	4,457	6,134	13,082	26,583	51,750	7.8	8.3	7.9	7.3	6.9
Pwani	583	828	1,206	2,862	6,277	12,938	6.0	9.8	9.0	8.2	7.5
Rukwa + Katavi	1,046	1,656	2,052	3,372	5,262	7,763	8.0	5.5	5.1	4.6	4.0
Ruvuma	1,141	1,795	2,184	3,401	4,919	6,469	7.8	5.0	4.5	3.8	2.8
Shinyanga + Simiyu	1,877	2,733	3,399	5,654	8,962	13,504	6.5	5.6	5.2	4.7	4.2
Singida	634	851	1,047	1,686	2,558	3,627	5.0	5.3	4.9	4.3	3.6
Tabora	1,190	1,748	2,197	3,765	6,191	9,776	6.6	5.9	5.5	5.1	4.7
Tanga	1,438	2,149	2,821	5,419	10,064	18,113	6.9	7.0	6.7	6.4	6.1
Tanzania (Mainland)	30,934	46,004	59,796	112,031	203,118	357,134	6.8	6.8	6.5	6.1	5.8
Zanzibar Total	742	1,166	1,444	2,372	3,701	5,458	7.8	5.5	5.1	4.5	4.0
Tanzania Total	31,676	47,169	61,239	114,403	206,819	362,592	6.9	6.7	6.4	6.1	5.8

Source: Actual data year 2010 and 2016 by NBS, Tanzania.

In 2016, the per capita GDP (in 2007 price) of Dar es Salaam was 1.43 million TZS, leading the entire nation for that year. It will grow 4.6 times to 6.53 million TZS by 2050 . Other high income regions following Dar es Salaam are Pwani Region (5.74 million TZS), Arusha Region (5.65 million TZS), Lindi Region (5.14 million TZS), and Mwanza Region (4.95 million TZS). Meanwhile, the gap between the highest and the lowest per capita GDP was 2.5 times in 2016, but it widens to 5.1 times in 2050 indicating expanding income disparities amongst regions.

As has been found in many studies made to date, the level of per capita GDP has a significant influence on the timing of introducing modern energy. Based on this concept we assume that LPG will be introduced when per capita GDP exceeds 1 million TZS (2007 price) per year. In terms of nominal price in 2016 it is about 2.2 million TZS.

Table 5.3-4 GDP per Capita Projection by Reginal (Real GDP, 2007 price)

Region	Actual(1,000 TZS/person)		Projection (1,000 TZS/person)				Annual Average Growth Rate (%)				
	2010	2016	2020	2030	2040	2050	2016/ 2010	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Arusha	935	1,144	1,384	2,195	3,500	5,647	3.4	4.9	4.7	4.8	4.9
Dar es Salaam	1,304	1,431	1,700	2,614	4,091	6,526	1.6	4.4	4.4	4.6	4.8
Dodoma	489	593	734	1,229	2,059	3,470	3.3	5.5	5.3	5.3	5.4
Iringa + Njombe	1,347	1,323	1,542	2,211	3,148	4,472	-0.3	3.9	3.7	3.6	3.6
Kagera	509	652	740	1,007	1,378	1,900	4.2	3.2	3.1	3.2	3.3
Kigoma	426	570	643	864	1,177	1,625	5.0	3.1	3.0	3.1	3.3
Kilimanjaro	868	1,161	1,337	1,871	2,619	3,685	5.0	3.6	3.4	3.4	3.5
Lindi	701	1,005	1,222	1,959	3,155	5,139	6.2	5.0	4.8	4.9	5.0
Manyara	762	950	1,082	1,499	2,115	3,047	3.7	3.3	3.3	3.5	3.7
Mara	673	878	982	1,278	1,650	2,109	4.5	2.9	2.7	2.6	2.5
Mbeya + Songwe	883	1,061	1,241	1,825	2,722	4,134	3.1	4.0	3.9	4.1	4.3
Morogoro	709	906	1,073	1,623	2,489	3,880	4.2	4.3	4.2	4.4	4.5
Mtwara	715	931	1,086	1,571	2,280	3,342	4.5	3.9	3.8	3.8	3.9
Mwanza + Geita	676	882	1,083	1,788	2,961	4,949	4.5	5.3	5.1	5.2	5.3
Pwani	552	691	913	1,733	3,176	5,737	3.8	7.2	6.6	6.2	6.1
Rukwa + Katavi	706	928	1,030	1,317	1,683	2,140	4.7	2.6	2.5	2.5	2.4
Ruvuma	862	1,197	1,321	1,641	1,981	2,280	5.6	2.5	2.2	1.9	1.4
Shinyanga + Simiyu	614	811	915	1,218	1,616	2,135	4.7	3.1	2.9	2.9	2.8
Singida	482	566	631	811	1,028	1,276	2.7	2.8	2.5	2.4	2.2
Tabora	547	679	765	1,023	1,379	1,879	3.7	3.0	2.9	3.0	3.1
Tanga	732	961	1,149	1,777	2,776	4,402	4.6	4.6	4.5	4.6	4.7
Tanzania (Mainland)	751	941	1,102	1,628	2,440	3,726	3.8	4.0	4.0	4.1	4.3
Zanzibar Total	598	794	879	1,119	1,424	1,803	4.8	2.6	2.4	2.4	2.4
Tanzania Total	747	937	1,096	1,613	2,409	3,667	3.9	4.0	3.9	4.1	4.3

Source: Actual data year 2010 and 2016 by NBS, Tanzania.

5.3.2 Regional Energy Demand Forecast

1) Final Energy Demand Forecast by Region

Applying the concept developed for the national energy consumption as discussed in Appendix D, the final energy demand of Dar es Salaam in 2016 is estimated to be 32.4% (2,704 ktoe) of the national total. Dar es Salaam will continue to be the largest energy consumption area in the country, consuming 16,147 ktoe (43.2%) in 2050. In 2050, other regions such as Mwanza Region (2,617 ktoe, 7.0%), Arusha Region (2,178 ktoe, 5.8%), and Tanga Region (2,147 ktoe, 5.7%) are ranked among the highest energy consumers. All of these regions are areas where industrial activities are relatively strong.

Among them, energy demand in Mtwara Region will expand fast at an AAGR of 19.0% between 2016 and 2020; thereafter it drops to 5.3% during the next ten years. This is because a new cement plant (capacity: 600 thousand tonnes per year) started production in 2016 and will start to consume natural gas in 2018. Instead of the moderate projection for later years, development of gas-based industry in Lindi and Mtwara regions, located along the trunk gas pipeline, may completely change the future industrial energy consumption picture in these regions.

On the other hand, in Tanzania's inland western region, where population is smaller and economic activity is not too strong, energy demand is mainly composed of the household sector and the demand size is small. Looking at the projection results for 2050, the western region's energy demand is low, represented by figures such as 426 ktoe in Singida Region, 531 ktoe in Mara Region, 551 ktoe in Manyara Region, and 561 ktoe in Ruvuma Region.

Table 5.3-5 Final Energy Demand Projection by Region

Region	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Arusha	231	337	426	792	1,477	2,178	6.1	6.4	6.4	4.0
Dar es Salaam	1,491	2,704	3,476	6,053	10,292	16,147	6.5	5.7	5.5	4.6
Dodoma	214	260	299	458	674	1,120	3.5	4.3	3.9	5.2
Iringa + Njombe	152	215	231	318	446	670	1.8	3.3	3.4	4.2
Kagera	228	278	306	391	496	797	2.4	2.5	2.4	4.9
Kigoma	206	258	285	398	545	889	2.5	3.4	3.2	5.0
Kilimanjaro	179	216	240	364	545	861	2.7	4.2	4.1	4.7
Lindi	89	147	142	205	272	393	-0.8	3.8	2.8	3.8
Manyara	137	173	189	253	336	551	2.3	2.9	2.9	5.1
Mara	173	197	216	271	334	531	2.3	2.3	2.1	4.8
Mbeya + Songwe	306	449	540	776	1,058	1,623	4.7	3.7	3.1	4.4
Morogoro	232	287	316	457	639	1,032	2.4	3.8	3.4	4.9
Mtwara	135	157	316	528	697	952	19.0	5.3	2.8	3.2
Mwanza + Geita	475	631	722	1,099	1,650	2,617	3.4	4.3	4.1	4.7
Pwani	121	170	194	294	450	695	3.3	4.2	4.4	4.4
Rukwa + Katavi	164	216	238	332	443	701	2.5	3.4	2.9	4.7
Ruvuma	147	172	187	258	356	561	2.1	3.2	3.3	4.6
Shinyanga + Simiyu	301	349	379	489	635	1,010	2.1	2.6	2.7	4.7
Singida	129	148	162	210	269	426	2.3	2.6	2.5	4.7
Tabora	215	265	288	377	490	797	2.1	2.7	2.7	5.0
Tanga	445	526	534	937	1,465	2,147	0.4	5.8	4.6	3.9
Tanzania (Mainland)	5,770	8,155	9,686	15,259	23,570	36,698	4.4	4.6	4.4	4.5
Zanzibar Total	158	192	215	310	434	682	2.9	3.7	3.4	4.6
Tanzania Total	5,928	8,347	9,901	15,569	24,003	37,381	4.4	4.6	4.4	4.5

Source: JICA Study Team

2) Industrial Energy Demand Forecast by Region

Industrial energy demand by region is projected under several bold assumptions. As for coal consumption, distribution of cement plants (including their capacity) and limestone mines are considered. Natural gas demand is calculated assuming areas for possible natural gas supply and start-up timing (2025). Petroleum, biomass and electricity demand in the industrial sector is calculated based on the scale of respective regional GDP. For the case of LPG, the timing of installation of LPG storage facilities in each region is considered as the key to start consumption in the industrial sector.

Among the industrial sector energy consumption in 2016, Dar es Salaam and Tanga Region consumed 353 ktoe (30.6% of the nationwide figure) and 239 ktoe (20.7%), respectively. These two regions account for 51.3% of the energy demand of Tanzania's industrial sector. Both are port cities and industries have been developed taking advantage of this. In the same year, Mwanza Region (61 ktoe) and Mbeya Region (47 ktoe) consumed relatively high volume of energy compared to other regions.

Among the projection results for 2050, Dar es Salaam and Tanga Region will continue to expand their industry utilising the advantage of port and transport infrastructure. At the same time, areas such as Mwanza Region, Mbeya Region and Mtwara Region are considered to have high potential to expand their industry in the future and industrial energy demand in these regions is expected to increase considerably.

Table 5.3-6 Industrial Energy Demand Projection by Region

Region	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Arusha	16	30	33	67	112	177	2.4	7.5	5.3	4.7
Dar es Salaam	154	353	442	732	1,141	1,706	5.8	5.2	4.5	4.1
Dodoma	10	19	22	57	104	178	4.8	9.7	6.2	5.6
Iringa + Njombe	17	31	33	50	74	103	1.6	4.1	4.1	3.4
Kagera	12	25	26	39	58	81	1.4	3.9	4.1	3.4
Kigoma	9	18	20	29	44	63	1.6	4.1	4.3	3.6
Kilimanjaro	14	28	30	58	89	130	1.8	6.6	4.4	3.9
Lindi	6	62	52	95	135	176	-4.3	6.2	3.5	2.7
Manyara	11	21	23	35	54	80	2.0	4.3	4.6	4.0
Mara	12	23	24	33	46	59	0.9	3.2	3.5	2.6
Mbeya + Songwe	23	47	96	165	243	334	19.6	5.5	4.0	3.2
Morogoro	16	30	33	62	104	163	2.4	6.5	5.2	4.6
Mtwara	9	17	164	324	430	524	76.5	7.0	2.9	2.0
Mwanza + Geita	29	61	71	128	233	396	3.8	6.1	6.2	5.4
Pwani	6	12	14	30	58	103	5.7	7.5	6.9	6.0
Rukwa + Katavi	11	23	23	32	46	60	1.0	3.3	3.5	2.7
Ruvuma	12	25	26	35	47	56	0.8	3.1	3.0	1.9
Shinyanga + Simiyu	19	38	40	58	84	114	1.4	3.8	3.8	3.0
Singida	7	12	12	18	25	32	1.3	3.7	3.5	2.6
Tabora	12	24	25	37	56	77	1.4	3.9	4.1	3.4
Tanga	224	239	195	384	539	699	-5.0	7.0	3.5	2.6
Tanzania (Mainland)	628	1,138	1,406	2,467	3,721	5,312	5.4	5.8	4.2	3.6
Zanzibar Total	8	16	17	25	36	49	1.5	3.9	3.7	3.0
Tanzania Total	636	1,154	1,424	2,492	3,758	5,361	5.4	5.8	4.2	3.6

Source: JICA Study Team

3) Transport Energy Demand Forecast by Region

The IEA energy statistics on Tanzania's transport sector include only gasoline and diesel. Currently, rail, marine and air transport are active, but there is no data and information to confirm the fuel consumption of these fields[36]. In addition, in the absence of statistical data related to

[36] Railways and ships are mainly consuming diesel or heavy oil, there is a possibility that they are included in diesel consumption.

automobiles in each region, we calculated the regional fuel consumption in the transport sector assuming fuel consumption per unit of economic activity level (GDP) of each region. Although it is difficult to make accurate analysis by this method, as the use of automobiles is largely related to the income and economic activities of the people, the scale and trend of the energy consumption of the transport sector by region can be assessed to some extent.

In the year 2016, the transport energy demand was concentrated in the areas with higher economic activities and urbanisation such as Dar es Salaam (1,608 ktoe, 70.0%), Arusha Region (103 ktoe, 4.5%), Mwanza Region (81 ktoe, 3.5%), and Mbeya Region (74 ktoe, 3.2%). These four regions will continue to be the highest transport energy consuming centres in the country until 2050; transport energy demand in these regions will expand to 9,741 ktoe (70.0%), 626 ktoe (4.5%), 473 ktoe (3.4%) and 322 ktoe (2.3%), respectively. Meanwhile, transport energy demand in Tanga Region, Morogoro Region, and Kilimanjaro Region are also increasing at relatively high rates.

There are many points left for future discussion relating to energy demand in the transportation sector in particular concerning the railway, aviation and marine transport sectors. Also, the possibility of introducing CNG vehicles (taxis etc.) should be considered especially in urban areas.

Table 5.3-7 Transport Energy Demand Projection by Region

Region	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/2016	2030/2020	2040/2030	2050/2040
Arusha	51	103	136	235	396	626	7.2	5.6	5.3	4.7
Dar es Salaam	795	1,608	2,121	3,656	6,156	9,741	7.2	5.6	5.3	4.7
Dodoma	22	45	59	102	171	271	7.2	5.6	5.3	4.7
Iringa + Njombe	14	24	29	50	80	117	5.5	5.4	4.8	3.9
Kagera	7	16	26	45	83	147	12.9	5.8	6.3	5.8
Kigoma	11	27	36	68	121	195	7.4	6.5	6.0	4.9
Kilimanjaro	14	29	38	66	111	175	7.2	5.6	5.3	4.7
Lindi	5	7	9	15	27	45	6.9	5.4	6.0	5.3
Manyara	6	12	16	30	57	100	7.8	6.2	6.6	5.8
Mara	9	11	18	31	57	100	13.2	5.7	6.2	5.8
Mbeya + Songwe	28	74	91	143	220	322	5.2	4.7	4.4	3.9
Morogoro	11	21	28	49	82	129	7.2	5.6	5.3	4.7
Mtwara	9	18	22	39	65	98	6.2	5.8	5.2	4.2
Mwanza + Geita	39	81	106	190	311	473	7.0	5.9	5.1	4.3
Pwani	11	31	37	57	86	123	4.9	4.4	4.2	3.6
Rukwa + Katavi	12	26	35	63	105	160	7.2	6.1	5.2	4.3
Ruvuma	10	14	19	35	63	105	7.4	6.4	6.0	5.3
Shinyanga + Simiyu	11	22	32	56	104	180	10.0	5.6	6.4	5.7
Singida	5	8	13	24	43	76	11.9	6.4	6.1	5.8
Tabora	9	19	25	46	86	151	8.3	6.0	6.6	5.8
Tanga	35	72	95	163	274	434	7.2	5.6	5.3	4.7
Tanzania (Mainland)	1,116	2,267	2,993	5,161	8,696	13,768	7.2	5.6	5.4	4.7
Zanzibar Total	19	30	38	62	98	147	6.1	5.1	4.7	4.2
Tanzania Total	1,135	2,297	3,030	5,223	8,794	13,915	7.2	5.6	5.3	4.7

Source: JICA Study Team

4) Commercial Energy Demand Forecast by Region

Commercial sector is expanding basically in line with urbanisation ratio and increase of urban population. The energy demand in the commercial sector is calculated by assuming average energy consumption per capita by energy source and multiplying the urban population of each region. Dar es Salaam has already reached 100% in the official announcement of the urbanisation ratio. As the per capita energy consumption intensity in the commercial sector in Dar es Salaam may be higher than that for other regions, we apply the national average for simplicity at this moment.

Dar es Salaam is the area where urbanisation is the most advanced in Tanzania; energy demand of the commercial sector in 2016 is estimated to be 209 ktoe which accounts for 31.9% of the national total. However, as urbanisation progresses in other regions, the share of Dar es Salaam in 2050 will decrease relatively, falling to 23.5% of the total. Urban population will also increase in other cities and their commercial sector will become active. Especially during the period from 2016 to 2020 and 2020 to 2030, the demand for commercial energy will increase with high growth rate in most regions. As supply infrastructure of modern energies such as electricity and LPG is lacking in Tanzania, charcoal may dominate for the time being to accommodate urban needs for modern energy. In order to prevent health damage and deforestation due to increased use of charcoal, it is necessary to hasten the supply system of urban energy to replace charcoal.

Table 5.3-8 Commercial Energy Demand Projection by Region

Region	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Arusha	21	25	37	93	203	323	9.9	9.6	8.1	4.8
Dar es Salaam	163	209	250	386	572	941	4.5	4.5	4.0	5.1
Dodoma	12	13	19	41	78	138	9.9	7.8	6.7	5.9
Iringa + Njombe	17	19	25	49	91	142	7.0	6.9	6.3	4.5
Kagera	8	13	20	34	55	98	12.5	5.3	4.8	5.9
Kigoma	13	21	28	48	72	121	6.9	5.6	4.0	5.4
Kilimanjaro	15	14	20	49	97	167	9.0	9.3	7.2	5.5
Lindi	6	5	7	11	17	30	6.9	5.0	4.6	5.6
Manyara	7	10	13	21	33	59	7.4	5.3	4.4	6.1
Mara	11	9	14	21	29	53	12.2	4.4	3.4	6.3
Mbeya + Songwe	33	59	70	102	134	210	4.5	3.8	2.8	4.6
Morogoro	23	33	41	67	92	150	5.7	4.9	3.2	5.0
Mtwara	11	14	17	28	39	66	5.4	5.3	3.1	5.5
Mwanza + Geita	45	65	85	151	237	378	7.0	5.9	4.6	4.8
Pwani	13	25	30	47	72	110	5.0	4.6	4.3	4.4
Rukwa + Katavi	14	21	26	41	52	85	6.2	4.7	2.3	5.0
Ruvuma	12	11	16	33	61	101	8.7	7.5	6.4	5.2
Shinyanga + Simiyu	13	18	27	50	91	155	10.7	6.4	6.2	5.5
Singida	6	7	11	21	37	64	12.6	6.9	6.0	5.6
Tabora	10	15	20	34	56	100	8.0	5.6	5.0	5.9
Tanga	17	27	41	109	247	392	11.4	10.2	8.5	4.8
Tanzania (Mainland)	468	632	817	1,437	2,365	3,883	6.6	5.8	5.1	5.1
Zanzibar Total	22	24	30	50	77	122	6.1	5.2	4.5	4.7
Tanzania Total	491	656	847	1,487	2,442	4,005	6.6	5.8	5.1	5.1

Source: JICA Study Team

5) Residential Energy Demand Forecast by Region

Energy demand in the residential sector is discussed in Appendix D and Section 5.1 in relation to ambiguity of the existing data and the difficulty to forecast the sectoral energy demand. Although the details of the above assessment will not be repeated, we have made a rough projection of the energy demand of the residential sector by region applying the same approach. Specifically, future per capita consumption of primary biomass, charcoal, oil (mainly kerosene) and electricity in the residential sector is assumed for urban and rural areas and the per capita figures are multiplied with regional population to calculate the energy demand.

With regard to LPG, its supply in each region starts with installation of receiving, storage and bottling facilities. For areas where supply has not been started as yet, it is assumed that the LPG demand will start when the region's GDP per capita (2007 price) reaches 1 million TZS. As for natural gas, except for Dar es Salaam and Mtwara where it has already been introduced, it will be introduced successively after 2025 in areas close to the natural gas supply infrastructure such as Dodoma, Morogoro, Tanga, Moshi and Arusha.

Table 5.3-9 Residential Energy Demand Projection by Region

Region	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/2016	2030/2020	2040/2030	2050/2040
Arusha	142	176	217	392	756	1,030	5.4	6.1	6.8	3.1
Dar es Salaam	380	534	663	1,279	2,424	3,761	5.6	6.8	6.6	4.5
Dodoma	167	180	193	246	295	481	1.8	2.5	1.8	5.0
Iringa + Njombe	103	138	139	163	190	290	0.3	1.6	1.5	4.3
Kagera	196	219	226	258	271	418	0.8	1.3	0.5	4.4
Kigoma	170	187	196	242	289	474	1.2	2.1	1.8	5.1
Kilimanjaro	134	142	148	184	233	363	1.0	2.2	2.4	4.5
Lindi	71	71	72	80	85	128	0.4	1.1	0.6	4.2
Manyara	112	127	134	159	175	278	1.2	1.7	1.0	4.8
Mara	139	151	155	176	182	282	0.8	1.3	0.3	4.5
Mbeya + Songwe	219	266	278	357	444	723	1.1	2.5	2.2	5.0
Morogoro	180	199	208	271	345	560	1.2	2.7	2.5	5.0
Mtwara	104	107	109	131	155	248	0.6	1.8	1.7	4.8
Mwanza + Geita	356	416	449	612	834	1,302	2.0	3.1	3.1	4.6
Pwani	90	102	111	157	229	348	2.1	3.5	3.8	4.3
Rukwa + Katavi	125	143	150	189	228	372	1.2	2.3	1.9	5.0
Ruvuma	111	119	124	148	173	276	0.9	1.8	1.5	4.8
Shinyanga + Simiyu	253	265	272	308	323	500	0.6	1.2	0.5	4.5
Singida	109	118	122	140	148	225	0.8	1.4	0.6	4.3
Tabora	180	203	211	246	266	419	0.9	1.6	0.8	4.6
Tanga	166	185	199	273	390	593	1.8	3.2	3.6	4.3
Tanzania (Mainland)	3,508	4,047	4,377	6,011	8,435	13,073	2.0	3.2	3.4	4.5
Zanzibar Total	107	121	128	168	213	347	1.5	2.8	2.4	5.0
Tanzania Total	3,615	4,168	4,505	6,179	8,649	13,420	2.0	3.2	3.4	4.5

Source: JICA Study Team

Based on the above condition setting, residential energy demand in each region is calculated. During the super long period through 2050, two phenomena are observed: (1) In the areas such as Dar es Salaam and Arusha Region where modern energies are already introduced, residential energy demand will grow fast at more than 5% through 2040. This is because modernisation of life becomes more popular increasing demand for modern energies such as electric power, city gas and LPG, and (2) In areas other than these two regions, residential energy demand will increase at a relatively low rate through 2020. Then, the growth rate will gradually rise to 3.1% -

5.1% for the period between 2040 and 2050. At present in these latter regions, more than 80% of the energy for the residential sector is supplied with primary biomass and charcoal. Deforestation is a serious environmental issue facing regional governments and strict measures are being taken against logging of forests and trees. This situation will suppress the supply of primary biomass and charcoal by 2030, while use of modern energy like electricity and LPG will be promoted in place of them. Transition from primary biomass and charcoal to modern energy sources in the residential sector in each region may come to a turning point by 2030. Then, regions will enter the period of shifting to modern energy one after another.

6) Agriculture and Other Energy Demand Forecast by Region

The energy demand in the agricultural sector and other sector indicated by historical data is very low. It is only 23 ktoe in agricultural sector and 49 ktoe in other sector according to statistical data of 2016. The agricultural sector's energy demand is mainly for agricultural equipment and irrigation equipment. However, because the statistics for agricultural output, equipment and irrigation facilities in each of the region cannot be obtained, we have estimated the trend for the per capita energy consumption per rural population and multiply the figures with rural population to project regional agricultural energy demand.

Table 5.3-10 Agricultural and Other Energy Demand Projection by Region

Region	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Arusha	1.9	2.7	3.5	6.3	11.3	21.0	6.6	5.9	6.1	6.4
Dar es Salaam	0.0	0.0	0.0	0.0	0.0	0.0				
Dodoma	2.9	4.2	5.8	12.7	26.0	50.5	8.4	8.2	7.5	6.8
Iringa + Njombe	1.4	2.6	3.4	6.0	10.5	18.8	6.6	5.8	5.8	6.0
Kagera	3.7	5.3	6.9	14.4	28.6	53.8	6.9	7.6	7.1	6.5
Kigoma	2.9	3.8	5.2	10.1	19.1	35.7	7.6	7.0	6.5	6.5
Kilimanjaro	2.1	3.0	4.0	7.6	14.1	25.1	7.2	6.7	6.4	6.0
Lindi	1.2	1.6	2.2	4.2	8.0	14.4	7.1	7.0	6.5	6.1
Manyara	2.0	3.0	4.0	8.5	17.1	32.4	8.1	7.8	7.2	6.6
Mara	2.4	3.7	4.8	9.9	19.6	36.8	6.8	7.6	7.1	6.5
Mbeya + Songwe	3.0	3.6	4.9	9.1	17.2	33.0	7.4	6.5	6.6	6.8
Morogoro	2.6	3.4	4.4	8.2	15.5	29.6	7.0	6.3	6.6	6.7
Mtwara	1.6	2.1	2.7	5.0	9.0	16.4	6.9	6.2	6.0	6.2
Mwanza + Geita	5.2	7.3	9.6	18.3	35.0	67.9	7.3	6.6	6.7	6.9
Pwani	1.2	1.2	1.6	2.9	5.4	10.6	7.2	6.2	6.4	7.0
Rukwa + Katavi	1.9	2.7	3.5	6.7	12.7	24.4	7.2	6.6	6.6	6.8
Ruvuma	1.7	2.6	3.5	6.8	12.8	23.1	7.4	6.9	6.6	6.1
Shinyanga + Simiyu	4.6	6.3	8.3	17.0	33.3	61.9	7.1	7.5	6.9	6.4
Singida	2.0	2.9	3.8	7.7	15.3	28.8	7.1	7.4	7.1	6.5
Tabora	3.3	4.7	6.4	13.4	26.6	50.3	7.8	7.7	7.1	6.6
Tanga	2.6	3.4	4.5	8.2	15.0	28.1	6.9	6.2	6.3	6.5
Tanzania (Mainland)	50.2	70.2	93.0	183.0	352.0	662.5	7.3	7.0	6.8	6.5
Zanzibar Total	1.2	1.8	2.4	4.7	9.1	17.7	7.4	6.7	6.8	6.9
Tanzania Total	51.3	72.1	95.4	187.7	361.1	680.1	7.3	7.0	6.8	6.5

Note: Other energy demand including the non-energy use sector.
Source: JICA Study Team

As shown in Table 5.2-10 in the above, the energy demand in the agricultural sector is predominantly in the western area including Mwanza Region (67.9 ktoe, 10.0% of national total in 2025), Shinyanga Region (61.9 ktoe, 9.1%), Kagera Region (53.8 ktoe, 7.9%), Dodoma Region (50.5 ktoe, 7.4%) and Tabora region (50.3 ktoe, 7.4%) and so on. Excluding Dar es Salaam, energy demand in agricultural sector in each region is expected to expand rapidly as the agricultural sector is modernised and mechanised. Even with this estimate, the AAGR in many regions will continue to be higher than 6.5% until 2050.

5.3.3 Regional Gas Demand Outlook

Following the final energy demand for each sector by region discussed in the previous section, this section considers the prospects for gas demand in each region.

1) LPG Demand Outlook

According to EWURA, LPG storage facilities have been installed in many regions by the end of December 2017, except for Mtwara Region, Lindi Region, Rukwa Region (including Katavi Region), Mala Region and Simiyu Region. LPG storage facilities are built in all of the regional capital city.

Source: JICA Study Team

Figure 5.3-2 Capacity of LPG Storage Facility by Region (end of December 2017)

Among these cities, the capacity of LPG storage facilities in 10 cities are 23 tonnes. For others, 96 tonnes in Dodoma Municipal, 96 tonnes in Mbeya City, 78 tonnes in Iringa City, 71 tonnes in Shinyanga City. Dar es Salaam (7,000 tonnes), Tanga City (1,073 tonnes), Arusha City (405 tonnes), Mwanza City (246 tonnes) and Moshi City (110 tonnes) have relatively large LPG storage facilities. Dar es Salaam and Tanga have a port infrastructure and play a role as the windows of LPG import for Tanzania. Arusha City and Moshi City have long been importing LPG from Kenya by land transport; recently they have started to import via the Tanga City terminal. Currently, 6,000 tonnes of LPG storage facilities by Mihan Tanzania Limited Company and 2,800 tonnes by Manjis Logistics Limited are under construction in Kigamboni district of Dar Es Salaam and they are scheduled to start operation at the beginning of 2019. As of December 2017, there are 9,382 tonnes of LPG storage facilities nationwide, and LPG import amount in the same year was statistically recorded as 107,263 tonnes.

According to EWURA, LPG retail licenses have been issued to a total of seven companies as of the end of 2017. Among them, Oryx Energies Tanzania Limited (Switzerland) has the largest capacity, totalling 4,710 tonnes. In Arusha City, four LPG retailers are selling gas, three of whom import LPG from Kenya on land. Lake Gas Limited is conducting land transportation from Tanga City to Arusha.

LPG demand forecasts is carried out considering the above-mentioned LPG supply status. In the estimation, hypothetical timing of facility installation is set and the volume of LPG supply is estimated according to the size of the storage facilities in each region. For regions where supply has not been started yet, it is assumed that the LPG demand will start when the region's GDP per capita (2007 price) reaches 1 million TZS.

In 2016, as the import window of Tanzania, Dar es Salaam 56 ktoe (46.2%), Arusha Region 25 ktoe (20.6%) and Tanga Region 8 ktoe (6.9%) have consumed 73.6% of the total of LPG demand in Tanzania. In the same year LPG was introduced into 17 areas, and the use of LPG spread to 18 areas in 2018. In this forecast, it is assumed that the supply of LPG will expand to all regions by 2020. To materialise this, construction of infrastructure for LPG retail delivery is required, while LPG demand will expand mainly in urban areas of these regions.

Table 5.3-11 Capacity of LPG Storage Facility by Owner and by Region (Unit: tonnes)

Region	Oryx Energies Tanzania Limited	Lake Gas Limited	Manjis Gas Limited	Orange Gas Limited	Mihan Gas Tanzania Limited	Acer Petroleum Tanzania Limited	Oilcom Tanzania Limited	Total
Mbeya	50				46			96
Iringa	25	30			23			78
Shinyanga	25				46			71
Mwanza	200				46			246
Kilimanjaro	110							110
Dodoma	50				46			96
Arusha		55	180	120		50		405
Morogoro					23			23
Tanga		1,050			23			1,073
Ruvuma					23			23
Njombe					23			23
Singida					23			23
Tabora					23			23
Manyara					23			23
Geita					23			23
Kagera					23			23
Kigoma					23			23
Dar es Salaam	4,250	750			1,500		500	7,000
Total	4,710	1,885	180	120	1,937	50	500	9,382

Source: EWURA

In 2050, LPG demand will grow in major cities such as Dar es Salaam, Arusha, Tanga and Mwanza amounting to 1,899 ktoe (38.4% of national total), 905 ktoe (18.3%), 469 ktoe (9.5%), 399 ktoe (8.1 %), respectively. In addition, local governments are implementing policies to curb the use of primary biomass and charcoal to cope with depletion of forestry resources, and it would be possible that LPG demand will expand at a much faster pace in the future.

Table 5.3-12 LPG Demand Projection by Region

Region	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Arusha	5	25	71	253	687	905	30.0	13.6	10.5	2.8
Dar es Salaam	11	56	157	544	1,462	1,899	29.4	13.3	10.4	2.6
Dodoma	0	2	7	28	77	109	33.2	15.0	10.4	3.6
Iringa + Njombe	0	2	7	30	81	122	37.2	16.3	10.7	4.1
Kagera	0	1	3	12	33	48	34.3	15.5	10.4	3.8
Kigoma	0	1	3	12	33	48	34.3	15.5	10.4	3.8
Kilimanjaro	0	3	10	42	115	164	33.4	15.1	10.5	3.6
Lindi	0	0	1	6	15	21		14.7	9.8	3.6
Manyara	0	0	2	7	19	27		14.7	9.9	3.6
Mara	0	0	1	4	9	13		14.7	9.8	3.6
Mbeya + Songwe	0	1	5	22	60	88	35.5	15.8	10.5	3.9
Morogoro	0	2	6	23	63	87	32.0	14.5	10.4	3.4
Mtwara	0	0	1	6	15	21		14.7	9.8	3.6
Mwanza + Geita	2	10	29	108	292	399	31.4	14.2	10.5	3.2
Pwani	0	4	11	40	106	145	31.1	14.1	10.4	3.2
Rukwa + Katavi	0	0	1	5	12	17		15.1	10.0	3.7
Ruvuma	0	1	5	20	56	81	35.4	15.8	10.6	3.9
Shinyanga + Simiyu	0	2	5	24	65	98	37.1	16.4	10.5	4.2
Singida	0	1	3	12	33	48	34.3	15.5	10.4	3.8
Tabora	0	1	3	12	33	48	34.3	15.5	10.4	3.8
Tanga	2	8	28	117	326	469	35.0	15.5	10.8	3.7
Tanzania (Mainland)	20	120	358	1,328	3,592	4,858	31.5	14.0	10.5	3.1
Zanzibar Total	0	1	5	20	56	81	35.4	15.8	10.6	3.9
Tanzania Total	20	121	363	1,348	3,648	4,940	31.6	14.0	10.5	3.1

Source: JICA Study Team

2) Natural Gas Demand Outlook

Expansion of demand for LPG is determined by the balance between demand and supply in the market, but in the case of natural gas demand, the early introduction will require an enormous infrastructure investment, so government support by various measures are required. Currently, Dar es Salaam and Mtwara has already been supplied with natural gas via pipeline and gas is mainly consumed for gas-fired power generation. The natural gas for the industrial sector is mainly used by cement companies and some industries in Dar es Salaam and Mtwara. A city gas demonstration project for residential use is also being conducted in Dar es Salaam, wherein a total of 77 households are supplied with city gas under this system. In other region, the cement plant in Mtwara was converted to natural gas in 2018, but there are no other examples of natural gas utilisation yet.

Based on the above observation, it is assumed that in the future natural gas may be supplied in the area along the existing pipeline and hypothetically from the gas fields to be developed around Chalinze (Ruvu Basin). In this projection, it is assumed that natural gas supply will start from 2025 in Dodoma City, Morogoro Municipal, Tanga City, Moshi Municipal, and Arusha City. For other regions in the west, LPG will be used as the main source of gas due to constraints such as transportation cost and limited demand size. According to these assumptions, in 2050 Dar es Salaam will consume 1,439 ktoe (70.8%) annually as the largest natural gas demand site. In cities close to the source of natural gas, market demand will expand relatively fast; and in 2050, Mtwara Region will consume 176 ktoe (8.7%), Tanga Region 106 ktoe (5.2%), Arusha Region 97 ktoe (4.8%), Dodoma Region 78 ktoe (3.8%), Kilimanjaro Region 73 ktoe (3.6%), and Morogoro Region 66 ktoe (3.2%).

Table 5.3-13 Natural Gas Demand Projection by Region

Region	Actual (ktoe)		Projection (ktoe)					Annual Average Growth Rate (%)			
	2010	2016	2020	2025	2030	2040	2050	2025/ 2016	2030/ 2025	2040/ 2030	2050/ 2040
Arusha	0	0	0	14	24	47	97		12.5	6.7	7.6
Dar es Salaam	100	146	245	317	475	807	1,439	9.0	8.5	5.4	6.0
Dodoma	0	0	0	12	20	38	78		10.2	6.7	7.4
Iringa + Njombe	0	0	0	0	0	0	0				
Kagera	0	0	0	0	0	0	0				
Kigoma	0	0	0	0	0	0	0				
Kilimanjaro	0	0	0	10	19	35	73		13.7	6.4	7.4
Lindi	0	0	0	0	0	0	0				
Manyara	0	0	0	0	0	0	0				
Mara	0	0	0	0	0	0	0				
Mbeya + Songwe	0	0	0	0	0	0	0				
Morogoro	0	0	0	9	15	31	66		10.9	7.2	7.9
Mtwara	0	0	43	83	107	139	176		5.4	2.6	2.4
Mwanza + Geita	0	0	0	0	0	0	0				
Pwani	0	0	0	0	0	0	0				
Rukwa + Katavi	0	0	0	0	0	0	0				
Ruvuma	0	0	0	0	0	0	0				
Shinyanga + Simiyu	0	0	0	0	0	0	0				
Singida	0	0	0	0	0	0	0				
Tabora	0	0	0	0	0	0	0				
Tanga	0	0	0	18	30	54	106		10.7	6.2	6.9
Tanzania (Mainland)	100	146	288	462	691	1,151	2,034	12.2	8.4	5.2	5.9
Zanzibar Total	0	0	0	0	0	0	0				
Tanzania Total	100	146	288	462	691	1,151	2,034	12.2	8.4	5.2	5.9

Source: JICA Study Team

5.4 Gas Demand of Objective Regions

This section outlines the energy and gas demand prospects of the seven regions where the Group-A cities as the candidates for gasification project are located. Macro analysis is made as a first approach to understand the baseline of the potential gas demand with available data and several assumptions for the seven regions. As explained in Appendix D, we conducted the Regional Energy Demand Survey on these cities. We will discuss the realistic energy demand in these cities based on the survey in the next section.

5.4.1 Socio-economic Profile of Candidate Cities

1) Dodoma Region and Dodoma City

Dodoma Region is located in the central part of Tanzania about 450km west of the Indian ocean sea coast. The region is a relay point of transport as a crossing of arterial roads connecting east-west and north-south. For this reason, it is a consolidating area of agricultural crops in the central region. Dodoma is connected with Dar es Salaam by the Central Line of the railway for 486 km; it further extends toward Mwanza. Dodoma is an intermediate point of the railway system.

According to the estimation by the NBS, the population of Dodoma Region reached 2.27 million in 2016. The population has been increasing at an AAGR of 2.1% since 2012. Urban population was 394 thousand and rural population was 187 thousand and hence the urbanisation ratio was 17.4%. In 2016, the number of households is 94 thousand in urban areas and 499 thousand in rural areas. Dodoma is a trade centre for agriculture and livestock products in the central Tanzania, and many light industries such as flour mills and food processing are active. The nominal GDP of Dodoma Region in 2016 reached 3.0 trillion TZS (real GDP is 1.34 trillion TZS in real term of 2007 price), increased by 7.7% from the previous year. The average per capita nominal GDP is 1.34 million TZS in 2016.

Table 5.4-1 Outline of Dodoma Region and Dodoma City

Item	Unit	Dodoma Region		Dodoma City	
		2012	2016	2012	2016
Population	Person	2,083,588	2,264,508	410,956	446,640
Urban	Person	321,194	394,024	213,636	240,128
Rural	Person	1,762,394	1,870,484	197,320	206,512
Number of Household	Unit	453,844	590,106	94,040	100,827
Urban	Unit	71,376	90,817	47,475	53,362
Rural	Unit	382,468	499,290	46,566	47,465
GDP (Current Price)	Million TZS	1,904,068	3,029,944	167,459	209,921
GDP Growth Rate	%	5.5	7.7		
GDP per Capital	TZS/person	913,841	1,338,014	407,486	470,000

Source: NBS, Census 2012 and projection for 2016

In 1973 the Cabinet decided Dodoma City[37] as the capital of Tanzania and to transfer administrative functions of the capital from Dar es Salaam. In the same year the Capital Development Bureau was established and in 1976 the "Dodoma National Capital Master Plan" was announced. In February 1996 the legislature moved to Dodoma, but some administrative agencies still remained in Dar es Salaam. According to the 2012 census, the population of Dodoma City was 411 thousand. According to the estimation of the NBS, the population of the city reached 447 thousand in 2016; increased by an AAGR of 2.1% from 2012. The population of the city is 19.7% of the whole region. In 2016, the urban population was 240 thousand (53.8%), and the rural population was 207 thousand (46.2%) and the number of households was 53 thousand for urban and 47 thousand for rural areas.

The nominal GDP of Dodoma City in 2016 was 209.9 billion TZS, and the nominal GDP per capita is 470 thousand TZS, which is about a third of Dodoma Region. The major economic activity for Dodoma City is concentrated in agriculture and livestock industry accounting for about 75% of its GDP, and public service industry and light industries for about 25%. Among

[37] Dodoma Municipal was promoted to Dodoma City on April 26, 2018.

light industries, food processing (oil extraction, milling, and wine production) and wood processing are the principal ones.

2) Arusha Region and Arusha City

Arusha Region is located in the northern part of Tanzania and in the plateau above altitude of 1,000 m in the Eastern African Great Rift Valley. Many tourists visit Arusha as there are numerous world-famous sightseeing spots in the perimeter such as Serengeti National Park, Aldobay Gorge, Meru Mountain (altitude: 4,655 m) and Arusha National Park.

According to the census of 2012, Arusha Region has a population of 1.69 million. Based on this, the NBS estimated the population of 2016 to be 1.89 million, increasing at an AAGR of 2.8% since 2012. The population of the Arusha Municipal was estimated to be 730 thousand (38.6%), and the rural population was calculated as 1.16 million (61.4%). In the same year, the number of household was 469 thousand; 163 thousand households were distributed in urban areas, and 307 thousand households in rural areas. For rural households, the household size was 4.5 persons, compared to 3.8 persons in urban households. According to the announcement by the NBS, the nominal GDP of Arusha Region in 2016 was 4.9 trillion TZS (real GDP was 2.2 trillion TZS in 2007 price). The nominal per capita GDP was 2.58 million TZS. Applying the national GDP deflator of the same year, the Arusha Region has recorded a GDP growth rate of 7.0%.

Table 5.4-2 Outline of Arusha Region and Arusha City

Item	Unit	Arusha Region		Arusha City	
		2012	2016	2012	2016
Population	Person	1,694,310	1,890,653	416,442	464,701
Urban	Person	559,122	729,792	416,442	464,701
Rural	Person	1,135,188	1,160,861	0	0
Number of Household	Unit	378,825	469,204	103,377	116,175
Urban	Unit	124,249	162,694	103,377	116,175
Rural	Unit	254,576	306,509	0	0
GDP (Current Price)	Million TZS	2,929,003	4,876,972		249,097
GDP Growth Rate	%	5.9	7.0		
GDP per Capital	TZS/person	1,728,729	2,579,517		536,038

Source: NBS, Census 2012 and projection for 2016

Arusha City is the capital of Arusha Region. The population in 2016 was 465 thousand, which increased from 416 thousand in 2012 at an AAGR of 2.8%. The city's number of households in 2016 was 116 thousand, and the urbanisation rate has reached 100%. The nominal GDP in 2016 was 249.1 billion TZS, and the per capita nominal GDP was 536 thousand TZS.

The city is not only a tourism city, but also many international conferences and meetings are held and many international organisations have their headquarters here such as the East African Community and the African Human Rights Court. In the city, there are plenty of accommodations, restaurants and other service industries. Arusha city is connected with Nairobi, the capital of Kenya, by road and is also connected by railway from Mombasa port (Kenya) and Tanga port.

3) Kilimanjaro Region and Moshi Municipal

Kilimanjaro Region is located in the north of Tanzania, having the international borderline with Kenya in the north, and domestically bordering on Arusha Region in the west, Tanga Region in the south and Manyara Region in the southwest. The highest mountain of Africa, Kilimanjaro (altitude: 5,895 m) also known as Roof of Africa, is located at the regional border with the northern part of the Arusha Region.

According to the 2012 census, population of Kilimanjaro Region was 1.84 million and the population in 2016 is estimated to be 1.98 million, increasing at an AAGR of 1.8% since 2012. The urban population of Moshi City is estimated to be 417 thousand (23.7%) and the rural population to be 134.2 thousand (76.3%). The number of households was 499 thousand, wherein 115 thousand households are distributed in urban areas and 384 thousand households in rural areas. The average rural household size was 3.5 persons while the urban household 3.6 persons.

The nominal GDP of Kilimanjaro Region in 2016 was 4.6 trillion TZS (real GDP was 2.5 trillion TZS in 2007 price). Nominal per capita GDP was 2.62 million TZS. GDP growth rate of Kilimanjaro Region was 4.6%. Industries in Kilimanjaro Region mainly comprise agriculture and tourism. In agriculture, cultivation of sisal hemp and coffee are the main products and cultivation of corn is also active in recent years.

Table 5.4-3 Outline of Kilimanjaro Region and Moshi Municipal

Item	Unit	Kilimanjaro Region		Moshi Municipal	
		2012	2016	2012	2016
Population	Person	1,640,087	1,759,048	184,292	197,659
Urban	Person	397,375	416,894	184,292	197,659
Rural	Person	1,242,712	1,342,154	0	0
Number of Household	Unit	384,867	499,128	45,245	49,415
Urban	Unit		115,176	45,245	49,415
Rural	Unit		383,952	0	0
GDP (Current Price)	Million TZS	2,788,912	4,607,203		
GDP Growth Rate	%	3.8	4.6		
GDP per Capital	TZS/person	1,700,466	2,619,146		

Source: NBS, Census 2012 and projection for 2016

Moshi Municipal is the capital city of Kilimanjaro Region. Its population in 2016 was 198 thousand, which increased from 184 thousand in 2012 at an AAGR of 1.8%. In 2016, the number of households in the city is 49 thousand, and the city size is relatively small. Moshi Municipal is surrounded by agricultural areas and agricultural products are gathered there; main products are corn, sisal hemp and coffee. In particular, the branded coffee "Kilimanjaro" is famous. Also, tourism to guide climbing Mount Kilimanjaro is an important industry.

4) Tanga Region and Tanga City

Tanga Region is located in the north-eastern part of Tanzania, in contact with Kenya in the north, facing the Indian Ocean in the eastern part and across the Pemba Strait and the Zanzibar

Strait with the Zanzibar. The Pangani River, originating from Mount Kilimanjaro, flows through the central part of Tanga Region and pours into the Indian Ocean. Tanga Region belongs to the tropical climate of the Indian Ocean, with an annual average temperature of 26.3 ° C and rainfall of 1,290 mm per year.

According to the 2012 census, the population of Tanga Region was 2.045 million. The population in 2016 was 2.24 million increasing at an AAGR of 2.3% since 2012. Urban population is announced to be 765 thousand (34.2%), and the rural population 147 thousand (65.8%). The number of households in 2016 was 572 thousand, wherein the number of urban households was 132 thousand and rural households 439 thousand. In rural areas, the average household size was 3.6 persons and in urban areas 5.8 persons. The nominal GDP of Tanga Region in 2016 was 4.8 trillion TZS and the real GDP was 2.1 trillion TZS in 2007 price. The nominal per capita GDP was 2.17 million TZS.

Table 5.4-4 Outline of Tanga Region and Tanga City

Item	Unit	Tanga Region		Tanga City	
		2012	2016	2012	2016
Population	Person	2,045,205	2,236,086	273,332	298,842
Urban	Person	440,908	764,741	221,126	298,842
Rural	Person	1,604,297	1,471,345	52,206	0
Number of Household	Unit	435,583	572,083	61,141	67,919
Urban	Unit	96,708	132,417	49,311	67,919
Rural	Unit	338,875	439,666	11,830	0
GDP (Current Price)	Million TZS	2,884,020	4,845,840	789,899	1,156,181
GDP Growth Rate	%	4.0	7.2		
GDP per Capital	TZS/person	1,410,138	2,167,108	2,889,888	3,868,871

Source: NBS, Census 2012 and projection for 2016

Tanga City is the capital of Tanga Region. Population of Tanga City in 2016 was 299 thousand, and increasing from 273 thousand in 2012 at an AAGR of 2.3%. The estimated number of households in 2016 is 68 thousand, and the urbanisation rate has reached 100%. Nominal GDP in the same year reached 1.16 trillion TZS, accounting for a quarter of Tanga's total, with nominal GDP per capita being 3.9 million TZS.

Tanga City is a port city facing the Indian Ocean, and is an export port for sisal hemp, coffee and tea which are major agricultural products in the northern part of Tanzania. It used to be the centre of the colonial German East Africa. Along with the Mombasa port in the north and the Dar es Salaam port in the south, it is one of the important harbours located on the coast of East Africa. In recent years, many factories have been built in Tanga City utilising superior logistics of the port. Among them, energy-intensive industries such as Simba Cement (production capacity: 1 million tonnes per year) and Kilimanjaro Cement (production capacity: 10 thousand tonnes per year) and Tanga Lime Factory are in operation. Also, the construction of a crude oil pipeline from Uganda is proceeding and crude oil shipment from Tanga is expected to begin by 2020.

Table 5.4-5 Main Manufacturing in Tanga City

Name of Company	Activity
Kilimanjaro Cement	product: Cement Productivity: 10 thousand tonnes/year Fuel: petroleum coke, 108 thousand tonnes/year
Simba Cement	Fuel: Coal Cement Prodictivity: 3,000 tonnes/day Employee: 380
Tanga Fresh Limited	Productivity: Milk (125,000 liters/day) Fuel: LPG, Diesel
Pembe Flour Mills Ltd	Milling plant, import material Productivity: Flour (110 tonnes/day)
Tanga Lime Factory	Lime Process Productivity: 400 tonnes/day Fuel: petroleum cokes (64 tonnes/day), Electricity

Source: Interview on January 2018.

5) Morogoro Region and Morogoro Municipal

According to the 2012 census, the population of Morogoro Region was 2.22 million. Among them, urban population was 636 thousand (28.7%) and rural population 1,582 thousand (71.3%). According to the estimation by the NBS, the population in 2016 was 2.44 million, increasing at an AAGR of 2.4% since 2012. The urban population of Morogoro Region in 2016 increased rapidly at 12.4% to 1.01 million (41.6%), while the rural population decreased by 2.6% to reach 1.42 million (58.4%). In the same year the number of households was 656 thousand, of which 202 thousand (30.8%) were distributed in urban areas and 454 thousand (69.2%) in rural areas.

The nominal GDP of Morogoro Region in 2016 recorded 4.98 trillion TZS; grew by 4.8% compared with the previous year. In the four years after 2012, the high economic growth continued at an AAGR of 13.5%. Agricultural sector’s activity greatly contributed to Morogoro's GDP. Morogoro Region produces foods such as rice with the second largest production in the country, and corn, and supplies them to the domestic markets.

Table 5.4-6 Outline of Morogoro Region and Morogoro Municipal

Item	Unit	Morogoro Region		Morogoro Municipal	
		2012	2016	2012	2016
Population	Person	2,218,492	2,437,431	315,866	347,038
Urban	Person	636,058	1,013,971	305,758	347,038
Rural	Person	1,582,434	1,423,460	10,108	0
Number of Household	Unit	506,289	655,833	75,347	86,760
Urban	Unit		202,036	73,019	86,760
Rural	Unit		453,798	2,328	0
GDP (Current Price)	Million TZS	3,001,144	4,980,758		
GDP Growth Rate	%	4.1	4.8		
GDP per Capital	TZS/person	1,352,785	2,043,446		

Source: NBS, Census 2012 and projection for 2016

Morogoro Municipal is the capital of Morogoro Region. It is located inland at a midpoint of

Dar es Salaam and Dodoma City, and its roads and railways are developed since the colonial times. Construction of the new standard gauge railway started in 2017, and is scheduled to complete in 2019. The new station will be built in the suburbs of the current city. In parallel with this railway renovation, construction of the "Tungi Special Economic Zone (SEZ)" was announced in May 2016. Under the Plan, a land area of 10,620 acres will be developed under the three themes focusing on eco-residential areas, transportation hubs and university education and research centres.

According to the 2012 census, its population in 2012 was 316 thousand. The NBS estimated the population in 2016 to be 347 thousand and it has increased at an AAGR of 2.4% since 2012. Morogoro Municipal is located in the middle point of the road and railway heading for Dodoma City (260 km) from Dar es Salaam (196 km). Utilising this as the advantage in its strategy, development of industrial base has been promoted. Currently, relatively large enterprises located in and around Morogoro City are two tobacco processing factories and Mazava textile factory.

Table 5.4-7 Main Manufacturing in Morogoro Municipal

Name of Company	Activity
Mazava Fabrics & production E.A. Ltd.	sportswear for export (USA) Productivity: 1.3 million pieces Employee: 2,500
Tanzania Tobacco Processing Ltd.	An intermediate product of tobaco Productivity: 18 tonnes/hoour Employee: 2,000
Alliance One Tobacco Tanzania Ltd,	Intermediate and final product of tobaco

Source: Interview on 25th January 2018.

6) Mbeya Region[38] and Mbeya City

Mbeya City is connected with Dar es Salaam by road and railway (Tanzania & Zambia Railway Authority, TAZARA). The distance is 826 km, passing through Iringa City and Morogoro City. Roads and railways proceed further inland from the city of Mbeya, crossing the border with Zambia about 90 km ahead, to Kasama city in Zambia.

According to the 2012 census, the population of Mbeya Region was 271 thousand. According to the estimation by the NBS, it was 323 thousand in 2016, increased at 4.5% annually since 2012. Mbeya Region is an urbanized area after Dar es Salaam, and the urbanisation ratio reached 55.5% in 2016. According to the data, the rural population was rapidly decreasing at 5.6% since 2012, while the urban population has dramatically increased at 18.8%. However, this would not be a real increase or decrease in the natural population. In January 2016 a part of the western Mbeya Province was divided and Songwe province was established, and hence these abnormal statistical

[38] The Songwe area was divided from the Mbeya Region around January 2016, but since the statistical data of the past has not been divided, in the analysing work of this report, we deal with Mbeya Province by including Songwe Region.

changes may have occurred due to the change in the administrative district demarcation as a temporary phenomenon. According to the data, the number of households in 2016 was 826 thousands, which were distributed in the city 254 thousand (average household size of 7.1 persons), and the rural areas 571 thousand (household size 2.5 persons).

In 2016 the GDP of Mbeya Region was 7.7 trillion TZS and the economic growth rate was 7.0% compared to the previous year. The region's economy is the third largest in the country next to Dar es Salaam and Mwanza Region, and the region's share of the national GDP was 7.3%. During the four years since 2012, the region's economy showed high growth rate of 7.5% AAGR. Calculating from the data for 2016, the nominal per capita GDP in the same year was 239.3 thousand TZS, which increased by 7.4% compared with the previous year though real growth rate was 0.6%.

Mbeya Region is blessed with sufficient rainfall and fertile soil; agricultural and livestock industry is the most active economic activities. Mbeya produces the largest quantities of corn, rice, banana, potato, soybeans and wheat in the country as the important production base supplying food all over the country. As export crops, coffee, tea, cocoa and many more agricultural crops are cultivated.

With favourable conditions for stable supply of feed, livestock industry in Mbeya Region is very active. According to the regional government data of 2012, the agricultural sector shows that its contribution to the GDP has reached about 80%. Mbeya Region is also endowed with relatively abundant mineral resources, and mining industries such as gold, coal, limestone and marble are operating in the region. Mbeya’s industries comprise mainly small and medium scale food processing and mining, while Mbeya Cement, with an annual production capacity of 350 thousand tonnes has started production recently and there is a plan to expand its capacity to 700 thousand tonnes.

Mbeya City as the capital of the Region is located in the southwestern part of Tanzania and is located in the middle between Lake Tanganyika and Lake Malawi. It is connected with a road of about 90 km to the border with Zambia. Urban areas are located in the valley with an altitude of 1,700 m and is surrounded by high mountains. Mbeya city is located in the East African Great Rift Valley with 10 dormant volcanoes distributed in the adjacent area; the Ruongwe Mountain with an altitude of 2,981 m is designated as the National Forest Reserve, and the Kituro National Park, Ruaha National Park and Nya Lake Alongside are also famous tourist destinations. It is classified as subtropical highland climate; it is dry from June to October with low temperature, but humidity increases during the rainy season from November until May of the following year and the average temperature rises to 27 degrees Celsius. According to the 2012 National Census of the NBS, the population of Mbeya city was 385 thousand and in 2016 it was 425 thousand. Its population increased during the past four years at 2.5% per year on average. The number of households in the same year is estimated at 109 thousand. A Coca-Cola manufacturing plant and SBC Tanzania Ltd. (beverage) are in operation in the city.

Table 5.4-8 Outline of Mbeya Region and Mbeya City

Item	Unit	Mbeya Region*		Mbeya City	
		2012	2016	2012	2016
Population	Person	2,707,410	3,226,465	385,279	424,623
Urban	Person	898,112	1,791,777	385,279	424,623
Rural	Person	1,809,298	1,434,687	0	0
Number of Household	Unit	635,047	825,523	89,602	108,878
Urban	Unit		254,115	89,602	108,878
Rural	Unit		571,407	0	0
GDP (Current Price)	Million TZS	4,500,842	7,720,143		
GDP Growth Rate	%	5.6	7.0		
GDP per Capital	TZS/person	1,662,416	2,392,756		

Note: * Included Songwe Region.
Source: NBS, Census 2012 and projection for 2016

Table 5.4-9 Main Manufacturing in Mbeya City

Name of Company	Location	Activity
Mining Industry		
Kibo Mining PLC	Ilima	Coal
Kiwira Coal Mine Ltd.	Mbeya	Coal
Kabulo Coal Mine	Songwe	Coal
Mbeya Cement Co. Ltd. (Lafarge)	Songwe	Limestone
DEMCO	Saza	Gold
Consolidated Mines Ltd.	Songwe	Marble
Mans Minig Co.	Sangambi	Gold
Beverage Industry		
SBC Tanzania Ltd. (Pepsi)	Mbeya	Soft drink
Coca-Cola Kwanza Limited (CCK)	Mbeya	Soft drink
Mbozi Coffee Curing Ltd.	Mbozi	Processing
Tukuyu Tea Co.	Tukuyu	Processing

Source: Interview on January 2018.

7) Mwanza Region and Mwanza City

Mwanza Region is located in the north-western part of Tanzania, facing Lake Victoria, the largest in Africa. Mwanza City is connected by marine transport with the capital city of Kampala in Uganda and the city of Kisumu in Kenya. The railway transport and roads lead to Dar es Salaam.

According to the 2012 census, the population of Mwanza Region was 2.77 million. Among them, the urban population was 924 thousand (33.3%) and the rural population was 1.85 million (66.7%). According to the estimation by the NBS, its population is 3.12 million in 2016 and has increased at an AAGR of 3.0% since 2012. According to the estimation, urban population of Mwanza Region increased by 12.3% in 2016; the urban population in that year was 1.47 million (47.0%) while rural population decreased to 1.66 million (53.0%) at an average rate of 2.7% per year. In the same year, the number of households was 630 thousand, of which 243 thousand (38.5%) were living in urban areas and 387 thousand (61.5%) in rural areas. The nominal GDP of Mwanza Region in 2016 reached 10.1 trillion TZS (4.46 trillion TZS in 2007 price), which grew by 11.4% over the previous year. The agriculture and fishery are the sectors greatly contributing to the GDP of Mwanza Region. In particular, the "Nile perch" fish cultivation and a cluster of fish processing and export industries in Lake Victoria area are the main industry for this Region. Among agricultural products, cotton is actively cultivated and it is one of the important export items.

Mwanza City[39] is the capital of Mwanza Region. In 2012 its population was 706 thousand according to the census survey; the NBS announced the population in 2016 was 796 thousand having increased at an AAGR of 3.0% since 2012. The number of households in 2016 is estimated to be 169 thousand. Mwanza City is the second largest city in the country next to Dar es Salaam and is connected to Dar es Salaam by the Tanzanian Railway Central Line and the national highway.

Table 5.4-10 Outline of Mwanza Region and Mwanza City

Item	Unit	Mwanza Region*		Mwanza City	
		2012	2016	2012	2016
Population	Person	2,772,509	3,122,992	706,453	795,758
Urban	Person	924,221	1,467,806	706,453	795,758
Rural	Person	1,848,288	1,655,186	0	0
Number of Household	Unit	486,184	630,094	144,174	169,310
Urban	Unit		242,659	75,263	87,106
Rural	Unit		387,434	0	0
GDP (Current Price)	Million TZS	5,619,758	10,050,581		
GDP Growth Rate	%	6.4	11.4		
GDP per Capital	TZS/person	2,026,958	3,218,254		

Note: * Included Geita Region.
Source: NBS, Census 2012 and projection for 2016

5.4.2 Outlook on Energy and Gas Demand

1) Dodoma Region

The final energy demand in Dodoma Region in 2016 is estimated to be 260 ktoe. The final energy demand in the region will increase at an AAGR of 3.5% during 2016-2020 and will expand with an AAGR of 4.3%, 3.9% and 5.2% every 10 years thereafter until 2050, when it reaches 1,120 ktoe. The demand make-up by sector in 2016 was residential (69.0%), transport (17.2%), industrial (7.2%), commercial (5.1%), and agriculture (1.6%). By 2050, the share of energy demand in the transport sector will increase from 17.2% to 24.2%, the industrial sector from 7.2% to 15.9%, the commercial sector from 5.1% to 12.3%, the agricultural sector from 1.6% to 4.5%. In contrast, the residential sector will decrease from 69.0% to 43.0%.

[39] Mwanza City is mainly composed by Nyamagana Districts and Ilemela Districts.

Table 5.4-11 Final Energy Demand by Sector: Dodoma Region

Sector	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/2016	2030/2020	2040/2030	2050/2040
Industry	10	19	22	57	104	178	4.8	9.7	6.2	5.6
Transport	22	45	59	102	171	271	7.2	5.6	5.3	4.7
Commercial	12	13	19	41	78	138	9.9	7.8	6.7	5.9
Residential	167	180	193	246	295	481	1.8	2.5	1.8	5.0
Agriculture	3	4	6	13	26	50	8.4	8.2	7.5	6.8
Total	214	260	299	458	674	1,120	3.5	4.3	3.9	5.2
Share (%)										
Industry	4.7	7.2	7.5	12.4	15.4	15.9				
Transport	10.3	17.2	19.7	22.2	25.4	24.2				
Commercial	5.6	5.1	6.4	8.9	11.5	12.3				
Residential	78.0	69.0	64.4	53.7	43.8	43.0				
Agriculture	1.3	1.6	1.9	2.8	3.9	4.5				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

With regard to the energy sources in 2016, primary biomass accounts for 49.7% (128 ktoe) of the total energy demand, 71.2% of the energy supply is supported by biomass including charcoal at 21.5% (55 ktoe). After introduction of LPG in 2015 and natural gas in 2025 or so, the use of modern energy to diversify the energy supply will progress.

Table 5.4-12 Final Energy Demand by Energy Source: Dodoma Region

Energy Source	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/2016	2030/2020	2040/2030	2050/2040
Coal	0	0	0	0	0	0				
Natural Gas	0	0	0	20	38	78			6.7	7.4
LPG	0	2	7	28	77	109		15.0	10.4	3.6
Oil	32	55	71	123	212	339	6.5	5.6	5.6	4.8
Primary Biomass	133	128	106	95	52	37	-4.6	-1.1	-5.9	-3.3
Charcoal	37	55	84	103	71	63	11.2	2.0	-3.6	-1.3
Electricity	11	13	23	67	180	428	14.0	11.4	10.4	9.1
Solar	1	4	8	22	44	66	23.4	10.2	7.4	4.0
Total	213	257	299	458	674	1,120	3.9	4.3	3.9	5.2
Share (%)										
Coal	0.0	0.0	0.0	0.0	0.0	0.0				
Natural Gas	0.0	0.0	0.0	4.3	5.7	6.9				
LPG	0.0	0.6	2.4	6.2	11.4	9.8				
Oil	15.1	21.6	23.8	26.9	31.5	30.3				
Primary Biomass	62.3	49.7	35.4	20.8	7.7	3.3				
Charcoal	17.3	21.5	28.2	22.5	10.6	5.6				
Electricity	5.0	5.2	7.6	14.6	26.6	38.2				
Solar	0.3	1.4	2.7	4.7	6.6	5.9				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

In 2050, the share of petroleum products (transportation fuel) will reach 30.3% (339 ktoe), electricity 38.2% (428 ktoe), natural gas 6.9% (78 ktoe), LPG 9.8% (109 ktoe) and solar PV (off-grid) 5.9% (66 ktoe). On the other hand, the share of primary biomass will shrink from 49.7% in 2016 to 3.3%, and charcoal from 21.5% to 5.6%.

2) Arusha Region

The final energy demand in Arusha Region in 2016 is estimated at 337 ktoe. It will increase at an AAGR of 6.1% during 2016-2020, and the growth rate will gradually decline thereafter to the AAGR of 6.4% over the next 20 years. It will grow at an AAGR of 4.0% in the period from 2040 to 2050, reaching 2,178 ktoe in 2050. The composition of sectoral demand in 2016 is residential (52.1%), transport (30.7%), industry (8.8%), commercial (7.5%) and agriculture (0.8%). This sectoral energy demand composition reflects the economic structure of Arusha Region being dominated by the tourism. In particular the shares of the transport sector and the commercial sector are higher than other regions. The share of energy demand by sector in 2050 will increase from 7.5% to 14.8% in the commercial sector, from 0.8% to 1.0% in the agriculture sector but decreases from 52.1% to 47.3% in the residential sector, from 30.7% to 28.8% in transport sector and from 8.8% to 8.1% in industrial sector.

As for energy demand by energy sources in 2016, Arusha Region did not consume coal because the region does not have heavy industry or energy industry. Oil as transportation fuel is the main energy demand, which was 116 ktoe (35.9%) in 2016. Next, the primary biomass was 114 ktoe (35.3%), charcoal 50 ktoe (15.6%), LPG 17 ktoe (5.3%), electricity 23 ktoe (7.1%), and solar (off-grid) 3 ktoe (0.8%). LPG supply in Arusha began in the first half of the 2000s, and is mainly supplied overland from Kenya. Since the tourism industry is a key industry, conversion from primary biomass fuels to modern energy has been advanced since an early time. Arusha is the region with the second highest LPG penetration rate next to Dar es Salaam. However, since it is far from the natural gas supply sources, we assume that introduction of natural gas can be realised at around 2025 with a slight delay behind other regions.

Table 5.4-13 Final Energy Demand by Sector: Arusha Region

Sector	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Industry	16	30	33	67	112	177	2.4	7.5	5.3	4.7
Transport	51	103	136	235	396	626	7.2	5.6	5.3	4.7
Commercial	21	25	37	93	203	323	9.9	9.6	8.1	4.8
Residential	142	176	217	392	756	1,030	5.4	6.1	6.8	3.1
Agriculture	2	3	4	6	11	21	6.6	5.9	6.1	6.4
Total	231	337	426	792	1,477	2,178	6.1	6.4	6.4	4.0
Share (%)										
Industry	6.8	8.8	7.7	8.5	7.6	8.1				
Transport	22.1	30.7	32.0	29.7	26.8	28.8				
Commercial	9.0	7.5	8.7	11.7	13.7	14.8				
Residential	61.3	52.1	50.8	49.4	51.2	47.3				
Agriculture	0.8	0.8	0.8	0.8	0.8	1.0				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

Table 5.4-14 Final Energy Demand by Energy Source: Arusha Region

Energy Source	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/2016	2030/2020	2040/2030	2050/2040
Coal	0	0	0	0	0	0				
Natural Gas	0	0	0	24	47	97			6.7	7.6
LPG	5	17	71	253	687	905	43.0	13.6	10.5	2.8
Oil	61	116	150	252	423	664	6.5	5.4	5.3	4.6
Primary Biomass	114	114	92	76	35	24	-5.3	-1.9	-7.3	-3.8
Charcoal	33	50	73	81	54	43	9.6	1.2	-4.0	-2.3
Electricity	17	23	35	93	208	413	11.6	10.1	8.4	7.1
Solar	0	3	6	13	23	32	21.4	8.4	5.7	3.5
Total	231	323	426	792	1,477	2,178	7.2	6.4	6.4	4.0
Share (%)										
Coal	0.0	0.0	0.0	0.0	0.0	0.0				
Natural Gas	0.0	0.0	0.0	3.1	3.2	4.4				
LPG	2.1	5.3	16.7	32.0	46.5	41.6				
Oil	26.4	35.9	35.1	31.8	28.7	30.5				
Primary Biomass	49.5	35.3	21.5	9.5	2.4	1.1				
Charcoal	14.3	15.6	17.0	10.3	3.7	2.0				
Electricity	7.4	7.1	8.3	11.7	14.1	18.9				
Solar	0.2	0.8	1.4	1.7	1.5	1.5				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

Among energy sources, the share of LPG will expand from 5.3% in 2016 to 41.6% in 2050, whereas the share of primary biomass will decrease from 35.3% in the same period to 1.1% and charcoal from 15.6% to 2.0%. Conversion of consumer fuel from primary biomass to modern energies will occur. In addition, the electricity demand for the grid will rapidly expand from 23 ktoe (7.1%) in 2016 to 413 ktoe (18.9%) in 2050.

3) Kilimanjaro Region

The final energy demand in Kilimanjaro Region in 2016 is estimated to be 216 ktoe. Since the key industry in the region is agriculture, growth rate of the final energy demand of the region is estimated to be moderate compared to other regions. The AAGR for 2016-2020 will be 2.7%, which will rise to 4.2% in the following 10 years, but then decelerate gradually to 4.1% in 2030-2040 and 4.7% in 2040-2050. The composition of sectoral demand in 2016 was residential (65.5%), transport (13.4%), industry (13.1%), commercial (6.6%) and agriculture (1.4%). Moshi Municipal is a tourist city and hence commercial and services sectors have developed, although this is limited only to the city of Moshi. Most parts of Kilimanjaro Region are engaged in agricultural activities. Among the sectoral energy demand estimated for 2050, the share of the residential sector will decrease from 65.5% to 42.2%, but still shows the largest energy consumption, followed by the transport sector (20.4%) commercial (19.4%), industry (15.1%), and agriculture (2.9%).

Table 5.4-15 Final Energy Demand by Sector: Kilimanjaro Region

Sector	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Industry	14	28	30	58	89	130	1.8	6.6	4.4	3.9
Transport	14	29	38	66	111	175	7.2	5.6	5.3	4.7
Commercial	15	14	20	49	97	167	9.0	9.3	7.2	5.5
Residential	134	142	148	184	233	363	1.0	2.2	2.4	4.5
Agriculture	2	3	4	8	14	25	7.2	6.7	6.4	6.0
Total	179	216	240	364	545	861	2.7	4.2	4.1	4.7
Share (%)										
Industry	7.9	13.1	12.7	15.9	16.4	15.1				
Transport	8.0	13.4	15.9	18.1	20.3	20.4				
Commercial	8.3	6.6	8.3	13.4	17.9	19.4				
Residential	74.7	65.5	61.4	50.5	42.8	42.2				
Agriculture	1.2	1.4	1.7	2.1	2.6	2.9				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

Composition of sectoral energy demand will not change significantly, but a major shift is seen among energy sources. Primary biomass was the main energy source in 2016, 103 ktoe (48.7%), followed by charcoal 45 ktoe (21.1%), oil (as transport fuel) 41 ktoe (19.1%), grid electric power 18 ktoe (8.7%), solar (off-grid) 3 ktoe (1.3%) and LPG 2 ktoe (1.1%). In 2050, grid electric power demand will increase to 315 ktoe (36.6%), oil 212 ktoe (24.6%), LPG 164 ktoe (19.0%), natural gas 73 ktoe (8.4%), charcoal 40 ktoe (4.6%), and solar (off-grid) 35 ktoe (4.1%), while primary biomass will decrease to 23 ktoe (2.6%). Shift to modern energy will advance while the share of primary biomass reduces to a mere 2.6%.

Table 5.4-16 Final Energy Demand by Energy Source: Kilimanjaro Region

Energy Source	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Coal	0	0	0	0	0	0				
Natural Gas	0	0	0	19	35	73			6.4	7.4
LPG	0	2	10	42	115	164	45.1	15.1	10.5	3.6
Oil	24	41	51	82	137	212	5.8	4.9	5.2	4.5
Primary Biomass	109	103	82	68	33	23	-5.7	-1.8	-6.8	-3.9
Charcoal	31	45	64	73	48	40	9.6	1.2	-4.0	-2.0
Electricity	14	18	27	66	150	315	9.9	9.3	8.6	7.7
Solar	0	3	6	14	25	35	21.9	8.9	6.2	3.3
Total	179	212	240	364	545	861	3.2	4.2	4.1	4.7
Share (%)										
Coal	0.0	0.0	0.0	0.0	0.0	0.0				
Natural Gas	0.0	0.0	0.0	5.2	6.5	8.4				
LPG	0.0	1.1	4.3	11.7	21.2	19.0				
Oil	13.4	19.1	21.2	22.6	25.1	24.6				
Primary Biomass	61.1	48.7	34.0	18.6	6.1	2.6				
Charcoal	17.3	21.1	26.9	20.0	8.9	4.6				
Electricity	7.9	8.7	11.2	18.0	27.6	36.6				
Solar	0.3	1.3	2.5	3.8	4.7	4.1				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

4) Tanga Region

The final energy demand in Tanga Region is estimated at 526 ktoe in 2016. The final energy demand estimation for 2016-2020 shows a low AAGR of 0.4%. Its background is that the coal supply declined due to the Tanzanian government's ban on coal import enforced in 2016. In particular the energy demand in the industrial sector will decrease from 239 ktoe in 2016 to 195 ktoe in 2020. This may be a temporary phenomenon, and be resolved in the medium to long term, and the final energy demand will steadily expand and reach 2,147 ktoe in 2050; the region will become the third largest energy consumer in Tanzania.

Composition of sectoral energy demand in 2016 is estimated as follows: industry (45.5%), residential (35.1%), transport (13.6%), commercial (5.1%), agriculture (0.6%). Sectoral energy demand composition in the year 2050 shows that four main demand sectors will dominate, namely, industry (32.6%), residential (27.6%), transport (20.2%), and commercial (18.3%), while the shares of agricultural (1.3%) sectors are relatively low.

As for the energy demand in Tanga Region by energy source, as mentioned above, since the coal import ban was enforced, coal consumption temporarily decreased from 226 ktoe in 2016 to 161 ktoe in 2020. But the coal demand thereafter will rise again. A significant change will be seen in the demand for grid electric power and primary biomass. Primary biomass will be reduced by half from 133 ktoe (24.9%) in 2016 to 30 ktoe (1.4%) by 2050, and the grid electric power will increase from 23 ktoe (4.3%) to 485 ktoe (22.6%) in the same period.

Table 5.4-17 Final Energy Demand by Sector: Tanga Region

Sector	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Industry	224	239	195	384	539	699	-5.0	7.0	3.5	2.6
Transport	35	72	95	163	274	434	7.2	5.6	5.3	4.7
Commercial	17	27	41	109	247	392	11.4	10.2	8.5	4.8
Residential	166	185	199	273	390	593	1.8	3.2	3.6	4.3
Agriculture	3	3	4	8	15	28	6.9	6.2	6.3	6.5
Total	445	526	534	937	1,465	2,147	0.4	5.8	4.6	3.9
Share (%)										
Industry	50.4	45.5	36.5	40.9	36.8	32.6				
Transport	8.0	13.6	17.7	17.4	18.7	20.2				
Commercial	3.8	5.1	7.8	11.7	16.8	18.3				
Residential	37.3	35.1	37.2	29.1	26.6	27.6				
Agriculture	0.6	0.6	0.8	0.9	1.0	1.3				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

Energy source composition in 2050 will be 485 ktoe (22.6%) for grid electric power, 481 ktoe (22.4%) for coal, 480 ktoe (22.3%) for oil, 469 ktoe (21.8%) for LPG, 106 ktoe (4.9%) for natural gas, 54 ktoe (2.5%) for charcoal, 42 ktoe (2.0%) for solar (off-grid), and 30 ktoe (1.4%) for primary biomass. Diversification of energy sources will progress in the region along with economic growth and modernisation.

Table 5.4-18 Final Energy Demand by Energy Source: Tanga Region

Energy Source	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Coal	209	226	161	302	402	481	-8.2	6.5	2.9	1.8
Natural Gas	0	0	0	30	54	106			6.2	6.9
LPG	2	6	28	117	326	469	47.0	15.5	10.8	3.7
Oil	47	85	109	182	306	480	6.4	5.3	5.3	4.6
Primary Biomass	134	133	108	91	44	30	-5.0	-1.7	-7.1	-3.7
Charcoal	38	58	86	99	67	54	10.1	1.4	-3.8	-2.1
Electricity	15	23	37	101	237	485	12.7	10.6	9.0	7.4
Solar	1	3	7	17	30	42	21.5	8.8	5.9	3.7
Total	445	534	534	937	1,465	2,147	0.0	5.8	4.6	3.9
Share (%)										
Coal	46.9	42.3	30.1	32.2	27.4	22.4				
Natural Gas	0.0	0.0	0.0	3.2	3.7	4.9				
LPG	0.5	1.1	5.2	12.4	22.2	21.8				
Oil	10.6	15.9	20.3	19.4	20.9	22.3				
Primary Biomass	30.1	24.9	20.2	9.7	3.0	1.4				
Charcoal	8.5	10.9	16.0	10.5	4.6	2.5				
Electricity	3.4	4.3	6.9	10.7	16.2	22.6				
Solar	0.1	0.6	1.3	1.8	2.0	2.0				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

5) Morogoro Region

The final energy demand in Morogoro Region in 2016 is estimated to be 287 ktoe. The final energy demand for 2016~2020 will increase at an AAGR of 2.4%, whereas the growth rate thereafter will be 3.8% for the period of 2020~2030, followed by 3.4% for 2030~2040 and 4.9% for 2040~2050.

The residential sector energy demand will increase from 199 ktoe in 2016 to 560 ktoe in 2050, but its share drops from 69.2% to 54.3%. This is the result of energy efficiency improvement in the residential sector reflecting the shift from the primary biomass to modern energies. There will be little structural change in other sectors. Energy demand in the agricultural sector shows a relatively high growth, as this region is an important agricultural area and fuel demand will increase as the agricultural sector will be gradually mechanised.

Morogoro Region has a large number of research and educational institutions in Tanzania, especially the agriculture-related organisations. In terms of the demand by energy source in 2016, primary biomass is the main energy source in the region at 147 ktoe (52.8%), followed by charcoal 65 ktoe (23.4%), oil 35 ktoe (12.4%), grid electric power 27 ktoe (9.6%), solar (off-grid) 3 ktoe (1.2%) and LPG 1 ktoe (0.5%).

Table 5.4-19 Final Energy Demand by Sector: Morogoro Region

Sector	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Industry	16	30	33	62	104	163	2.4	6.5	5.2	4.6
Transport	11	21	28	49	82	129	7.2	5.6	5.3	4.7
Commercial	23	33	41	67	92	150	5.7	4.9	3.2	5.0
Residential	180	199	208	271	345	560	1.2	2.7	2.5	5.0
Agriculture	3	3	4	8	15	30	7.0	6.3	6.6	6.7
Total	232	287	316	457	639	1,032	2.4	3.8	3.4	4.9
Share (%)										
Industry	6.7	10.6	10.6	13.7	16.2	15.8				
Transport	4.6	7.4	8.9	10.6	12.8	12.5				
Commercial	10.0	11.6	13.1	14.7	14.5	14.5				
Residential	77.7	69.2	66.0	59.3	54.1	54.3				
Agriculture	1.1	1.2	1.4	1.8	2.4	2.9				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

At present, the use of modern energy is low and 76.3% of the energy demand is supported by biomass. By 2050, however, the dependency on primary biomass and charcoal will decline to 3.3% and 6.0%, respectively, while the share of grid electric power expands from 9.6% in 2016 to 54.3% in 2050 reflecting popularisation of home and office appliances. LPG and natural gas will gradually penetrate and their market shares are forecast to become 8.5% and 6.4% in 2050, respectively.

Table 5.4-20 Final Energy Demand by Energy Source: Morogoro Region

Energy Source	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Coal	0	0	0	0	0	0				
Natural Gas	0	0	0	15	31	66			7.2	7.9
LPG	0	1	6	23	63	87		14.5	10.4	3.4
Oil	23	35	43	68	114	177	5.4	4.8	5.3	4.5
Primary Biomass	148	147	121	103	49	34	-4.8	-1.6	-7.2	-3.6
Charcoal	42	65	96	112	77	62	10.2	1.5	-3.7	-2.1
Electricity	18	27	43	118	274	560	12.4	10.7	8.8	7.4
Solar	1	3	8	18	32	46	21.6	8.9	6.0	3.8
Total	232	279	316	457	639	1,032	3.2	3.8	3.4	4.9
Share (%)										
Coal	0.0	0.0	0.0	0.0	0.0	0.0				
Natural Gas	0.0	0.0	0.0	3.4	4.8	6.4				
LPG	0.0	0.5	1.9	5.1	9.8	8.5				
Oil	9.8	12.4	13.5	14.9	17.9	17.1				
Primary Biomass	63.8	52.8	38.3	22.6	7.6	3.3				
Charcoal	18.3	23.4	30.4	24.4	12.0	6.0				
Electricity	7.9	9.6	13.5	25.7	42.9	54.3				
Solar	0.3	1.2	2.4	3.9	5.0	4.5				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

6) Mbeya Region

Final energy demand of Mbeya Region in 2016 is estimated to be 449 ktoe. The AAGR of the final energy demand in Mbeya Region will grow at 4.7% in the forecast period of 2016-2020, 3.7% in 2020-2030, 3.1% in 2030-2040, and 4.4% in 2040-2050. The final energy demand in 2050 will increase about 3.6 times to 1,623 ktoe compared with 2016. Among sectors, residential sector energy consumption will increase from 266 ktoe in 2016 to 723 ktoe in 2050, though its share will decline from 59.2% to 44.6%. Meanwhile, the industrial sector will expand from 10.5% to 20.6% in the same period, and transport sector will also keep expanding from 16.5% to 19.9%. There are various active industries operating in Mbeya Region while mining of coal, gold and limestone are also active. In addition, Mbeya Cement started production in 2017 and food processing industries are expected to develop fast.

Among energy sources in 2016, primary biomass was the main energy, 195 ktoe (46.6%), followed by oil at 88 ktoe (21.0%), charcoal 87 ktoe (20.9%), grid electric power 42 ktoe (10.2%), solar (off-grid) 4 ktoe (1.0%) and small amount of LPG 1.0 ktoe. The Mbeya Cement Factory, started operation in 2017 and receives coal from coal mines in the region. Demand for coal started in 2017 and it will gradually increase toward 2050, reaching 135 ktoe (8.3%). Demand expands also for grid electric power; this will greatly change the region's energy composition. Grid electric power demand was 10.2% of the total in 2016, and will increase to 51.2% in 2050. On the other hand, shares of primary biomass and charcoal will decrease to 2.8% and 5.3% in 2050, respectively.

Table 5.4-21 Final Energy Demand by Sector: Mbeya Region

Sector	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/2016	2030/2020	2040/2030	2050/2040
Industry	23	47	96	165	243	334	19.6	5.5	4.0	3.2
Transport	28	74	91	143	220	322	5.2	4.7	4.4	3.9
Commercial	33	59	70	102	134	210	4.5	3.8	2.8	4.6
Residential	219	266	278	357	444	723	1.1	2.5	2.2	5.0
Agriculture	3	4	5	9	17	33	7.4	6.5	6.6	6.8
Total	306	449	540	776	1,058	1,623	4.7	3.7	3.1	4.4
Share (%)										
Industry	7.6	10.5	17.8	21.3	23.0	20.6				
Transport	9.2	16.5	16.8	18.4	20.8	19.9				
Commercial	10.6	13.0	12.9	13.1	12.7	12.9				
Residential	71.6	59.2	51.6	46.0	42.0	44.6				
Agriculture	1.0	0.8	0.9	1.2	1.6	2.0				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

Table 5.4-22 Final Energy Demand by Energy Source: Mbeya Region

Energy Source	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Coal	0	0	45	84	113	135		6.5	2.9	1.8
Natural Gas	0	0	0	0	0	0				
LPG	0	1	5	22	60	88	46.4	15.8	10.5	3.9
Oil	44	88	111	169	261	381	6.1	4.3	4.5	3.8
Primary Biomass	183	195	168	142	66	45	-3.7	-1.6	-7.4	-3.6
Charcoal	53	87	133	154	107	86	11.1	1.5	-3.6	-2.2
Electricity	27	42	69	182	413	832	13.0	10.2	8.5	7.2
Solar	1	4	9	22	39	57	22.4	8.9	5.8	3.9
Total	306	417	540	776	1,058	1,623	6.7	3.7	3.1	4.4
Share (%)										
Coal	0.0	0.0	8.3	10.9	10.6	8.3				
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0				
LPG	0.0	0.3	0.9	2.8	5.6	5.4				
Oil	14.3	21.0	20.6	21.8	24.7	23.5				
Primary Biomass	59.6	46.6	31.0	18.3	6.2	2.8				
Charcoal	17.2	20.9	24.6	19.8	10.1	5.3				
Electricity	8.7	10.2	12.8	23.5	39.1	51.2				
Solar	0.3	1.0	1.7	2.8	3.7	3.5				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

7) Mwanza Region

Final energy demand in Mwanza Region in 2016 is estimated to be 631 ktoe. It will steadily increase at annual rates of 3.4-4.7% during the decades of projection to reach 2,617 ktoe in 2050. Sectoral composition of energy demand in 2016 was for residential 416 ktoe (65.9%), transport 81 ktoe (12.9%), commercial 65 ktoe (10.3%), industrial 61 ktoe (9.7%), and agricultural 7 ktoe (1.2%). By 2050, industrial sector will have greatly expanded to 15.19% (396 ktoe), and the transport sector will also expand from 12.9% in 2016 to 18.1%. Commercial sector slightly expands from 10.3% to 14.4%, while residential sector shrinks to 49.8%.

Table 5.4-23 Final Energy Demand by Sector: Mwanza Region

Sector	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Industry	29	61	71	128	233	396	3.8	6.1	6.2	5.4
Transport	39	81	106	190	311	473	7.0	5.9	5.1	4.3
Commercial	45	65	85	151	237	378	7.0	5.9	4.6	4.8
Residential	356	416	449	612	834	1,302	2.0	3.1	3.1	4.6
Agriculture	5	7	10	18	35	68	7.3	6.6	6.7	6.9
Total	475	631	722	1,099	1,650	2,617	3.4	4.3	4.1	4.7
Share (%)										
Industry	6.2	9.7	9.8	11.6	14.1	15.1				
Transport	8.1	12.9	14.7	17.3	18.8	18.1				
Commercial	9.5	10.3	11.8	13.8	14.4	14.4				
Residential	75.1	65.9	62.2	55.7	50.5	49.8				
Agriculture	1.1	1.2	1.3	1.7	2.1	2.6				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

Table 5.4-24 Final Energy Demand by Energy Source: Mwanza Region

Energy Source	Actual (ktoe)		Projection (ktoe)				Annual Average Growth Rate (%)			
	2010	2016	2020	2030	2040	2050	2020/ 2016	2030/ 2020	2040/ 2030	2050/ 2040
Coal	0	0	0	0	0	0				
Natural Gas	0	0	0	0	0	0				
LPG	2	7	29	108	292	399	43.9	14.2	10.5	3.2
Oil	63	107	137	235	389	591	6.4	5.5	5.2	4.3
Primary Biomass	291	301	252	222	109	77	-4.4	-1.3	-6.9	-3.4
Charcoal	83	133	200	240	169	139	10.7	1.8	-3.5	-1.9
Electricity	35	51	87	256	621	1,306	14.2	11.3	9.3	7.7
Solar	1	7	16	39	71	105	22.2	9.1	6.2	4.0
Total	475	607	722	1,099	1,650	2,617	4.4	4.3	4.1	4.7
Share (%)										
Coal	0.0	0.0	0.0	0.0	0.0	0.0				
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0				
LPG	0.4	1.1	4.0	9.8	17.7	15.2				
Oil	13.2	17.7	19.0	21.3	23.6	22.6				
Primary Biomass	61.3	49.6	34.9	20.2	6.6	2.9				
Charcoal	17.5	21.9	27.7	21.8	10.2	5.3				
Electricity	7.3	8.5	12.1	23.3	37.6	49.9				
Solar	0.3	1.2	2.2	3.5	4.3	4.0				
Total	100.0	100.0	100.0	100.0	100.0	100.0				

Source: JICA Study Team

In 2016, the primary biomass was the main energy source in Mwanza Region with consumption of 301 ktoe (49.6%), followed by charcoal 133 ktoe (21.9%), oil 107 ktoe (17.7%), grid electric power 51 ktoe (8.5%), solar (off-grid) 7 ktoe (1.2%) and LPG 7 ktoe (1.1%). In Mwanza Region, agriculture, forestry and fisheries are active; food processing industry is also active accordingly, and consumes certain amount of oil. Consumption of primary biomass is high because of its high population density. In future, however, primary biomass demand will gradually decline and its share will shrink to 2.9% in 2050. The same trend will be seen for charcoal. On the other hand, demand for grid electric power will increase rapidly with introduction of home and office appliances; its share will reach 49.9% in 2050.

5.5 Prospective Gas Demand Based on REDS

To understand the energy trends in the objective regions more in depth, the Regional Energy Demand Survey (REDS) was conducted in 2018. As analysed below, potential gas demands in provincial cities as well as at individual users are mostly small. It will take some time to prepare a firm project plan, solicit prospective customers and establish an affirmative sales plan to justify a gas supply project. In this context, we assume that the project will start operation in 2025 and examine prospective fuel demands for 2025 and 2030 that may be switched to natural gas.

5.5.1 Expected Fuel Demand as a Basis for Gasification

As the basis to consider the gas supply system to be developed at cities where natural gas pipeline is yet to be developed, we first consider the potential fuel demand at these cities applying the findings of the Regional Energy Demand Survey and macro model projection of the energy demand for the entire nation as explained below. This projection is made with many bold assumptions as data and information on regional energy consumption and impacting factors are limited. Starting with this rough sketch, demand scenarios for case setting will be formulated..

1) Urban Population

For estimation of the realistic potential demand for city gas, we assume population of the objective cities as below:

Starting from the NBS estimation of regional population for 2012 and 2017, it is assumed that:

a. Population growth rates of regions will maintain the same ratio to the national population growth rate.
b. Although the NBS assumes the same population growth rates for regions and their capitals between 2012 and 2017, we assume that people move to urban areas; population growth rates in cities will be accelerated by 100% -200% as shown in the Table 5.5-1.

Table 5.5-1 Future Population of Regions and Cities

Region	NBS Estimation		Growth Rate		Acceleration		Population			Share of the cities			Others (Population/Growth Rate)		
city	2012	2017		Share	2017-25	2025-30	2018	2025	2030	2018	2025	2030	2018	2025	2030
Arusha	1,694	1,943	2.8%		100%	100%	1,997	2,386	2,673				1,494	1,661	1,744
Arusha City	416	478	2.8%	24.6%	5.4%	5.1%	503	725	928	25.2%	30.4%	34.7%	1.9%	1.5%	1.0%
Dodoma	2,084	2,312	2.1%		200%	150%	2,361	2,702	2,945				1,877	1,975	2,030
Dodoma MC	411	456	2.1%	19.7%	6.0%	4.7%	483	727	915	20.5%	26.9%	31.1%	1.1%	0.7%	0.5%
Mbeya	1,709	1,929	2.5%		100%	100%	1,977	2,315	2,559				1,521	1,685	1,774
Mbeya CC	385	435	2.5%	22.6%	4.7%	4.5%	456	630	785	23.1%	27.2%	30.7%	1.8%	1.5%	1.0%
Morogoro	2,218	2,495	2.4%		100%	100%	2,555	2,977	3,281				2,183	2,468	2,651
Morogoro MC	316	355	2.4%	14.2%	4.6%	4.3%	372	509	629	14.5%	17.1%	19.2%	2.0%	1.8%	1.4%
Kilimanjaro	1,640	1,790	1.8%		100%	100%	1,822	2,041	2,194				1,294	1,369	1,394
Moshi	467	509	1.8%	28.5%	3.5%	3.5%	527	672	800	29.0%	32.9%	36.5%	1.1%	0.8%	0.4%
Mwanza	2,773	3,217	3.0%		100%	100%	3,315	4,021	4,548				2,445	2,711	2,790
Mwanza	706	820	3.0%	25.5%	6.0%	6.0%	869	1,311	1,757	26.2%	32.6%	38.6%	2.0%	1.5%	0.6%
Tanga	2,045	2,287	2.3%		100%	100%	2,338	2,703	2,963				2,019	2,268	2,421
Tanga City	273	306	2.3%	13.4%	4.5%	4.5%	319	435	542	13.7%	16.1%	18.3%	1.9%	1.7%	1.3%
Total	14,163	15,974	2.4%		2.3%	2.0%	16,364	19,145	21,163				12,834	14,136	14,805
Seven cities	2,975	3,359	2.5%	21.0%	5.1%	4.9%	3,530	5,009	6,357	21.6%	26.2%	30.0%	1.7%	1.4%	0.9%
Tanzania Mainland				6.7%											
	43,625	50,045	2.8%		2.6%	2.3%	51,432	61,473	68,858						

Source: JICA Study Team

As a result, while the population of the seven regions will increase by 17% by 2025 and 29% by 2030, population of core cities will increase by 30-50% by 2025 and 50-90% by 2030. This tendency of urbanisation would be intensified further if economic growth were accelerated by shift to secondary and tertiary industries.

2) Fuel Demand in Objective Cities

Based on the REDS and macro-model projection, we have estimated the fuel demand for the seven cities, which will increase from 398 ktoe in 2018 to 601 ktoe in 2025 and 852 ktoe in 2030. For the five cities excluding Mbeya and Mwanza, the increase will be from 321 ktoe in 2018 to 419 ktoe in 2025 and 586 ktoe in 2030. However, a substantial amount of coal and petro-coke are used in cement and lime factories in Tanga. As these plants may continue to use these cheaper fuels, potential fuel demand for natural gas switching would be much smaller as explained below.

a. Industrial Sector

Based on the understanding that the REDS covers most of the industrial energy demand in each region, we adopt the demand figures therein and apply the growth rates by energy type estimated for the national demand model to project regional demand as shown in Table 5.5-2. Among the listed energies, LPG, fuel oil, coal, petro-coke and biomass (firewood, agro-residues and charcoal) are the fuels that could be technically replaced with natural gas. The total fuel demand for the seven cities will increase from 116 ktoe in 2018 to 175 ktoe in 2025 and 217 ktoe in 2030. However, in view of the price competitiveness, coal and petro-coke used in large quantities at cement and lime factories would not be considered for such fuel switching.[40] Accordingly, the total fuel demand for the Group-A five cities will be 30.6 ktoe in 2025 and 38.0 ktoe in 2030.

Table 5.5-2 Industrial Sector Fuel Demand

	2018 (Regional Energy Demand Survey)							2025				2030				Fuel Demand		
	Motor Fuel	Fuel for heat				Electricity	Total	Motor fuel	Fuel	Electricity	Total	Motor fuel	Fuel	Electricity	Total	2018	2025	2030
		LPG Fuel Oil	Coal+ P-coke	Biomass	Sub-Total			6.1%	6.1%	6.6%		4.4%	4.4%	6.1%				
	toe	toe	toe	toe	toe	toe	toe	toe	toe	toe	toe	toe	toe	toe	toe	toe	toe	toe
Arusha	205	406	386	522	1,315	5,946	7,466	311	1,992	9,330	11,632	385	2,468	12,542	15,395	1,300	2,000	2,500
Dodoma	29	55	4,459	2	4,516	301	4,847	44	6,844	473	7,361	55	8,480	636	9,171	4,500	6,800	8,500
Mbeya	506	380	0	168	548	710	1,764	766	831	1,114	2,711	949	1,030	1,497	3,476	500	800	1,000
Morogoro	483	3,657	4,459	2,040	10,157	2,212	12,852	732	15,391	3,471	19,593	907	19,072	4,666	24,645	10,200	15,400	19,100
Moshi	2,398	569	0	1,103	1,672	1,127	5,197	3,634	2,534	1,768	7,936	4,504	3,140	2,377	10,020	1,700	2,500	3,100
Mwanza	5,447	12,945	0	4,761	17,706	7,688	30,841	8,254	26,831	12,062	47,147	10,228	33,249	16,215	59,692	17,700	26,800	33,200
Tanga	2,823	500	77,036	2,058	79,594	17,151	99,569	4,279	120,613	26,909	151,800	5,302	149,462	36,173	190,938	79,600	120,600	149,500
Cement +Lime	0	0	77,036	0	77,036	15,996	93,032	0	116,736	25,097	141,833	0	144,658	33,737	178,395	77,000	116,700	144,700
Others	2,823	500	0	2,058	2,558	1,155	6,537	4,279	3,877	1,812	9,968	5,302	4,804	2,436	12,542	2,600	3,900	4,800
Total: Seven Cities	11,892	18,513	86,341	10,654	115,508	35,135	162,535	18,020	175,034	55,126	248,180	22,330	216,901	74,105	313,336	115,500	175,000	216,900
	7.3%	11.4%	53.1%	6.6%	71.1%	21.6%	100.0%	7.3%	70.5%	22.2%	100.0%	7.1%	69.2%	23.7%	100.0%			
Excluding C&L in Tanga	11,892	18,513	9,305	10,654	38,472	19,139	107,975	18,020	58,298	30,029	106,348	22,330	72,243	40,368	134,941	38,500	58,300	72,200
	11.0%	17.1%	8.6%	9.9%	35.6%	17.7%	100.0%	16.9%	54.8%	28.2%	100.0%	16.5%	53.5%	29.9%	100.0%			
Total: Five Cities	5,939	5,188	86,341	5,725	97,254	26,737	129,930	9,000	147,373	41,951	198,323	11,152	182,623	56,393	250,168	97,300	147,400	182,600
Excluding C&L in Tanga	5,939	5,188	9,305	5,725	20,218	10,742	36,898	9,000	30,637	16,854	56,490	11,152	37,965	22,656	71,773	20,200	30,600	38,000

Source: JICA Study Team

Apart from the above calculation, we have sorted out large factories with fuel consumption of more than 20 toe a month from the REDS individual data sheets. In Japanese experience, LNG is supplied by tank trucks to those users who receive a bulk cargo at least once a month. The typical cargo size is 12-15 tonnes, or 14-18 toe. There are 19 such factories as listed in Table 5.5-3. These factories may be considered as the objective of the direct delivery of natural gas by tank trucks or bulk containers if not connected to the city gas system.

[40] In 2018, coal price delivered to a cement plant was \$120/ton with low heat value of around 4,000kcal/kg. This compares to \$7.3/MMBtu, which would be difficult to achieve with virtual pipeline natural gas.

Table 5.5-3 Large Factories Consuming 20 ktoe per Month or More

Large factories with potential monthly fuel demand more than 20 toe		Products	2018		2025 to grow at 6%			2030 to grow at 6%		
			Monthly	Annual	Annual	100%	70%	Annual	100%	70%
			toe	toe	toe	toe	toe	toe	toe	toe
Arusha	Tanzania Brewary Ltd.	Beer	34	404	608	600	400	813	800	600
	A to Z Textile	Textile	35	417	627	600	400	839	800	600
	Sub-total		68	821	1,235	1,200	900	1,652	1,700	1,200
Dodoma	Sunshine Industrial Limited	Cooking oil	372	4,459	6,705	6,700	4,700	8,973	9,000	6,300
	Sub-total		372	4,459	6,705	6,700	4,700	8,973	9,000	6,300
Mbeya	Tanzania Brewary Ltd	Beer	44	526	791	800	600	1,058	1,100	700
	Sub-total		44	526	791	800	600	1,058	1,100	700
Morogoro	21st Century Textile	Textile	543	6,517	9,799	9,800	6,900	13,113	13,100	9,200
	Alliance One Tobacco	Tobacco	115	1,381	2,077	2,100	1,500	2,780	2,800	1,900
	Tanzania Tobacco	Tobacco	188	2,258	3,396	3,400	2,400	4,544	4,500	3,200
	Sub-total		846	10,157	15,272	15,300	10,700	20,437	20,400	14,300
Moshi	Bonite Bottlers	Soft drinks	47	568	854	900	600	908	900	600
	Sub-total		47	568	854	900	600	908	900	600
Mwanza	Mwatex	Textile	170	2,036	3,061	3,100	2,100	4,097	4,100	2,900
	Nyakato Steel Mills	Steel	89	1,064	1,599	1,600	1,100	2,140	2,100	1,500
	Mwanza Wines	Wine	88	1,057	1,589	1,600	1,100	2,126	2,100	1,500
	Sayona Drinks	Soft drinks	110	1,316	1,978	2,000	1,400	2,647	2,600	1,900
	Serengetti Brewaries	Beer	954	11,443	17,206	17,200	12,000	23,026	23,000	16,100
	Nayanza bottling	soft drinks	52	627	942	900	700	1,261	1,300	900
	Sub-total		1,462	17,542	26,376	26,400	18,500	35,297	35,300	24,700
Tanga	Gulam Patter Coconut Oil	Cooking oil	63	761	1,144	1,100	800	1,531	1,500	1,100
	Kilimanjaro Cement	Cement	505	6,065	9,180	9,200	6,400	12,284	12,300	8,600
	Tanga Cement	Cement	5,443	65,322	98,870	98,900	69,200	132,311	132,300	92,600
	Tanga Fresh	Milk products	27	322	487	500	300	652	700	500
	Neelkanth Lime Ltd	Lime	479	5,754	8,709	8,700	6,100	11,654	11,700	8,200
	Sub-total		6,519	78,223	118,389	118,400	82,800	158,432	158,400	110,900
Total										
	7 cities		9,358	112,295	169,622	169,700	**118,800**	226,758	226,800	**158,700**
	5 cities		7,852	94,228	142,455	142,500	**99,700**	190,403	190,400	**133,300**
	5 cites excl. Cement and Lime		1,424	17,088	25,697	25,700	**18,000**	34,154	34,100	**23,900**

Groth rate @ 10 %

Large factories with potential monthly fuel demand more than 20 toe		Products	2018		2025 to grow at 10%			2030 to grow at 10%		
			Monthly	Annual	Annual	100%	70%	Annual	100%	70%
Total										
	7 cities		9,358	112,295	185,126	185,100	**129,600**	297,576	297,700	**208,200**
	5 cities		7,852	94,228	149,917	149,900	**105,000**	240,873	240,900	**168,500**
	5 cites excl. Cement and Lime		1,424	17,088	33,159	33,100	**23,300**	52,832	52,900	**36,900**

Source: JICA Study Team

Their fuel consumption is projected applying the macro-model growth rate of industrial fuel consumption likewise as above. The fuel consumption for seven cities is estimated to be 170 ktoe in 2025 and 227 ktoe in 2030. However, for the Group-A five cities excluding cement and lime factories in Tanga, it will be 26 ktoe in 2025 and 34 ktoe in 2030. If we assume a switching ratio of 70%, these will be 18.1 ktoe in 2025 and 23.9 ktoe in 2030. Unless energy intensive industry is specifically introduced, these will represent a realistic projection of the potential industrial fuel demand for possible switching to natural gas. If we apply a higher demand growth rate of annual 10%, these projections will become 23.3 ktoe for 2025 and 36.9 ktoe for 2030, which are only slightly more encouraging.

b. <u>Commercial and Public Services Sector</u>

The REDS provides information on energy consumption per entity in the commercial and public services, but does not provide aggregate volumes as they represent partial samples only. Therefore, as a first approach, we estimate the numbers of entities by sub-sector with bold assumptions as below based on the population projection for each city.

a. The number of universities and colleges in 2018 is a firm figure and will increase as population grows. The numbers of primary and secondary schools are estimated with school age population, enrolment ratio and school size.
b. The number of hospitals in 2018 is a firm figure and will increase as population grows. The number of clinics is estimated to be three times greater than the national average of one for 207,400 people in 2018.
c. The number of supermarkets and large shops is assumed one for 100,000 persons and that of smaller shops is assumed to be 20 times greater.
d. The number of hotels is assumed at five for 100,000 persons while it is 5 times greater for Arusha and three times greater for Moshi in view of their active tourism. Restaurants are 20 times more than them.
e. The number of business offices is assumed to be 10 for 100,000 persons.

Table 5.5-4 Commercial and Public Services Sector Entities and Fuel Demand

【2018】		Arusha	Dodoma	Mbeya	Morogoro	Moshi	Mwanza	Tanga	Total	5 cities				
											National total			
Population		503,192	483,411	455,701	371,601	527,424	869,323	319,370	3,530,023	2,204,999	51,431,727	51.02		
Hospital												2018	National Average	
	Hospital	3	1	4	2	5	1	2	18	13		86	598,043	
	Clinic	7	7	7	5	8	12	5	51	32	3 times	246	209,072	
School														
	University	4	2	2	4	4	2	2	20	16	Age	Composition	Enrollment	Student
	Secondary	34	33	31	25	36	59	22	263	150	14-17	9.3%	35%	480
	Primary	76	73	69	56	79	131	48	532	332	7-13	18.7%	90%	1120
Others											Per 100,000			
	Supermarket	5	5	5	4	5	9	3	36	22	1			
	Shop	101	97	91	74	105	174	64	706	441	20			
	Hotel	125	120	115	95	130	215	80	880	550	5	Arusha: 5 times, Moshi: 2 times		
	Restaurant	101	97	91	74	105	174	64	706	441	20	2 times		
	Offices	50	48	46	37	53	87	32	353	220	10			
Energy Consumption		toe	toe	toe	toe	toe	toe	toe	toe	toe				
Hospital	Fuel	33	15	42	22	52	20	22	207	145	At clinic,	10%	of hospitals	
	Electricity	153	153	153	109	175	263	109	1,116	700				
	Total	186	168	195	132	227	282	132	1,323	845				
School	Fuel	1,729	1,239	1,192	1,519	1,776	1,846	982	10,820	7,245	University,	10	times of secondary school	
	Electricity	3,510	3,401	3,198	2,582	3,705	6,084	2,262	26,683	15,459	Primary school not counted			
	Total	5,240	4,639	4,390	4,101	5,481	7,930	3,243	35,025	22,704				
Others	Fuel	1,374	1,321	1,265	1,039	1,431	2,370	877	9,679	6,043	Shop comsumes		5%	of supermarket
	Electricity	4,448	4,271	4,012	3,264	4,625	7,663	2,820	31,102	19,428	Restaurant consumes		10%	of hotels
	Total	5,822	5,592	5,277	4,303	6,056	10,033	3,697	40,781	25,471				
Total														
	Fuel	3,137	2,575	2,499	2,581	3,259	4,236	1,881	20,168	13,433				
	Electricity	8,111	7,825	7,363	5,955	8,505	14,010	5,191	56,960	35,587				
	Total	11,248	10,400	9,862	8,536	11,764	18,246	7,072	77,128	49,020				

(Table continued)

【2025】		Arusha	Dodoma	Mbeya	Morogoro	Moshi	Mwanza	Tanga	Total	5 cities				
											National total			
Population		724,977	727,019	630,251	508,677	672,485	1,310,718	434,956	5,009,083	3,068,114	61,473	thousand		
Hospital														
	Hospital	4	1	5	2	6	1	2	22	15				
	Clinic	10	10	9	7	10	19	6	71	43				
School														
	University	5	3	2	5	5	3	2	28	20	Age	Compositior	Enrollment	Student
	Secondary	56	56	49	39	52	101	34	263	237	14-17	9.3%	40%	480
	Primary	121	122	105	85	112	219	73	837	513	7-13	18.7%	100%	1120
Others											Per 100,000			
	Supermarket	7	7	6	5	7	13	4	49	30	1			
	Shop	145	145	126	102	134	262	87	1001	613	20			
	Hotel	180	36	32	25	68	66	22	429	331	5	Arusha: 5 times, Moshi: 2 times		
	Restaurant	145	145	126	102	134	262	87	1001	613	20	2 times		
	Offices	72	73	63	51	67	131	43	500	306	10			
Energy Consumption		toe	toe	toe	toe	toe	toe	toe	toe	toe				
Hospital	Fuel	54	22	64	29	76	31	28	304	209				
	Electricity	328	328	295	230	328	624	197	2,331	1,412				
	Total	382	350	359	259	404	655	225	2,635	1,620				
School	Fuel	2,993	2,428	1,948	2,513	2,880	3,699	1,525	17,985	12,338				
	Electricity	8,623	8,635	7,534	6,014	8,002	15,562	5,229	59,600	36,504				
	Total	11,616	11,064	9,482	8,527	10,882	19,260	6,754	77,585	48,843				
Others	Fuel	2,389	922	806	644	1,209	1,674	552	8,196	5,716				
	Electricity	9,582	9,289	8,072	6,533	8,654	16,784	5,572	64,487	39,631				
	Total	11,971	10,210	8,878	7,177	9,864	18,458	6,125	72,683	45,347				
Total														
	Fuel	5,435	3,371	2,818	3,186	4,165	5,404	2,105	26,485	18,263				
	Electricity	18,534	18,253	15,902	12,777	16,985	32,969	10,999	126,418	77,547				
	Total	23,969	21,624	18,719	15,963	21,150	38,374	13,104	152,903	95,810				

【2030】		Arusha	Dodoma	Mbeya	Morogoro	Moshi	Mwanza	Tanga	Total	5 cities				
Population		928,377	914,911	785,008	629,177	799,936	1,757,464	542,335	6,357,208	3,814,736	68,858	thousand		
Hospital														
	Hospital	4	1	5	3	6	2	3	24	17				
	Clinic	13	13	11	9	11	25	8	90	54				
School														
	University	6	3	3	5	5	3	3	28	22	Age	Compositior	Enrollment	Student
	Secondary	90	88	76	61	77	169	52	263	368	14-17	9.3%	50%	480
	Primary	155	153	131	105	134	294	91	1,063	638	7-13	18.7%	100%	1120
Others											Per 100,000			
	Supermarket	9	9	8	6	8	18	5	63	37	1			
	Shop	186	183	157	126	160	351	108	1271	763	20			
	Hotel	230	230	195	155	200	440	135	1585	950	5	Arusha: 5 times, Moshi: 2 times		
	Restaurant	186	183	157	126	160	351	108	1271	763	20	2 times		
	Offices	93	91	79	63	80	176	54	636	381	10			
Energy Consumption		toe	toe	toe	toe	toe	toe	toe	toe	toe				
Hospital	Fuel	238	103	274	175	319	202	171	1,483	1,007				
	Electricity	742	742	628	514	628	1,427	457	5,138	3,083				
	Total	980	845	902	689	947	1,629	627	6,621	4,089				
School	Fuel	2,600	2,045	1,837	1,924	2,201	3,449	1,421	15,478	10,192				
	Electricity	51,749	50,670	43,705	35,072	44,342	97,318	29,970	352,826	211,804				
	Total	54,349	52,715	45,542	36,996	46,544	100,767	31,392	368,304	221,995				
Others	Fuel	12,913	12,797	10,972	8,718	11,186	24,625	7,528	88,739	53,142				
	Electricity	20,976	20,648	17,710	14,207	18,051	39,605	12,184	143,382	86,066				
	Total	33,889	33,445	28,683	22,925	29,236	64,230	19,712	232,121	139,208				
Total														
	Fuel	15,751	14,945	13,084	10,818	13,706	28,276	9,120	105,700	64,340				
	Electricity	73,467	72,060	62,043	49,792	63,021	138,350	42,611	501,345	300,952				
	Total	89,218	87,005	75,127	60,610	76,727	166,627	51,731	607,045	365,292				

Source: JICA Study Team

Then, applying the energy consumption per unit for each sub-sector obtained from the REDS as shown in Table 5.5-5, the aggregate energy consumption is estimated. In this projection, fuel and electricity consumption per unit is assumed to increase at growth rates of per capita fuel and electricity consumption for the commercial and public services sector of the whole nation estimated by the macro model as discussed in Section 5.3. As a result, the total fuel consumption in the seven cities is estimated to increase from 20 ktoe in 2018 to 26 ktoe in 2025 and 106 ktoe in 2030; and in the five cities from 13 ktoe in 2018 to 18 ktoe in 2025 and 64 ktoe in 2030. Fuel consumption in the sector is expected to grow fast as the economy develops. However, the firm demand at the time of project formulation would be relatively small.

Table 5.5-5 Energy Consumption per Entity

	Hospital	Hotel	Super market	Public Service/Office	School	Total	Growth Rrate of Per Capita Consumption
	toe/y	toe/y	toe/y	toe/y	toe/y	toe/y	
【2018: Average per unit】							
Fuel	8.9	8.5	7.1	3.2	23.4	11.3	
Electricity	21.9	14.3	27.4	24.1	8.4	17.6	
Total	30.8	22.7	34.5	27.3	31.8	28.9	
【2025】							2018-2025
Fuel	10.8	10.2	8.6	3.9	28.2	13.6	2.7%
Electricity	32.8	21.4	41.1	36.2	12.7	26.4	6.0%
Total	43.6	31.6	49.7	40.0	40.9	40.0	3.7%
【2030】							2025-2030
Fuel	12.1	11.5	9.7	4.4	31.7	15.3	2.4%
Electricity	44.9	29.3	56.2	49.5	17.3	36.1	6.5%
Total	57.1	40.8	65.9	53.8	49.1	51.4	3.7%

Source: JICA Study Team

c. Household Sector

Energy consumption at households in the objective cities is estimated by applying the per capita energy consumption observed for each city in the REDS and multiplying the future population of these cities projected as shown in Table 5.5-1. Per capita energy consumption is considered in terms of kilogram oil equivalent (kgoe) and separately for traditional fuels such as firewood and charcoal, for fossil fuels such as LPG, kerosene and diesel, and for electricity. Per capita fuel consumption for cooking may remain relatively stable, while fuel consumption for hot water for bath and shower will increase along with income growth. Thus, categorized per capita energy consumption is projected multiplying the growth rates estimated by the macro model for the whole nation. As fuel modernisation may proceed faster in the urban areas, the above exercise may have resulted in slightly lower estimation for the objective cities.

Applying the above approach, fuel consumption in the objective cities will increase from 253 ktoe in 2018to 401 ktoe in 2025 and 576 ktoe in 2030. The traditional fuel consumption may level off at around 230-240 ktoe a year because of population increase despite that per capita consumption is projected to decrease by 21% between 2018 and 2025 and further 19% in the next five years. As the above estimation applies the present energy consumption structure, we should consider that the total fuel consumption can be the candidate for gasification in these cities. For the five Group-A cities, namely, Arusha, Dodoma, Morogoro, Moshi and Tanga, the total fuel consumption will increase from 160 ktoe in 2018 to 255 ktoe in 2025 and 363 ktoe in 2030.

Except for Mwanza where population may exceed one million in the early 2020s, the total fuel demand in 2025 at individual cities will be in the range of 40-60 ktoe a year; these individual numbers are more important to consider feasibility of the city gas system.

Table 5.5-6 Household Sector Energy Consumption

	Arusha	Dodoma	Mbeya	Morogoro	Moshi	Mwanza	Tanga	Total	5 cities	
【2018】										
Population	503,192	483,411	455,701	371,601	527,424	869,323	319,370	3,530,023	2,204,999	
Per Capita Energy Consumption (kg oil equivalent)										
Frewood+Charcoal	46.8	58.6	72.7	56.2	58.2	49.9	67.0	58.5	56.6	
Other fuel	17.2	11.6	11.3	12.6	20.0	12.9	17.2	14.5	15.9	
Fuel Total	64.0	70.2	83.9	68.8	78.2	62.8	84.2	73.0	72.5	
Electricity	8.2	12.3	8.3	13.5	11.8	7.8	10.7	10.0	11.2	
Total	72.2	82.5	92.2	82.3	90.1	70.6	95.0	83.0	83.7	
Aggregate Energy Consumption (toe: tons oil equivalent)										
Frewood+Charcoal	23,555	28,334	33,115	20,899	30,711	43,374	21,396	201,384	124,895	
Other fuel	8,639	5,598	5,130	4,682	10,548	11,240	5,500	51,338	34,967	
Fuel Total	32,194	33,933	38,246	25,581	41,259	54,614	26,896	252,722	**159,863**	
Electricity	4,121	5,927	3,761	5,013	6,245	6,785	3,432	35,285	24,739	
Total	36,315	39,860	42,006	30,595	47,504	61,399	30,328	288,007	**184,601**	Growth rate of per capita consumption for 2018-25
【2025】										
Population	724,977	727,019	630,251	508,677	672,485	1,310,718	434,956	5,009,083	3,068,114	
Per Capita Energy Consumption (kg oil equivalent)										
Frewood+Charcoal	37.9	47.4	58.8	45.5	47.1	40.4	54.2	46.0	45.8	-3.0%
Other fuel	40.7	27.5	26.7	29.9	47.4	30.7	40.8	34.2	37.3	13.1%
Fuel Total	78.6	74.9	85.5	75.4	94.5	71.0	95.1	80.2	83.0	
Electricity	16.2	24.3	16.3	26.7	23.5	15.5	21.3	19.7	22.2	10.3%
Total	94.8	99.2	101.9	102.1	118.0	86.5	116.3	99.9	105.2	
Aggregate Energy Consumption (toe: tons oil equivalent)										
Frewood+Charcoal	27,464	34,487	37,065	23,153	31,690	52,925	23,582	230,366	140,376	
Other fuel	29,514	19,965	16,825	15,197	31,891	40,185	17,761	171,339	114,329	
Fuel Total	56,979	54,452	53,891	38,350	63,582	93,110	41,343	401,705	**254,705**	
Electricity	11,763	17,660	10,304	13,596	15,774	20,268	9,260	98,625	68,053	
Total	68,741	72,112	64,195	51,946	79,355	113,378	50,604	500,330	**322,758**	Growth rate of per capita consumption for 2025-30
【2030】										
Population	928,377	914,911	785,008	629,177	799,936	1,757,464	542,335	6,357,208	3,814,736	
Per Capita Energy Consumption (kg oil equivalent)										
Frewood+Charcoal	31.0	38.8	48.1	37.2	38.5	33.0	44.3	37.5	37.4	-4.0%
Other fuel	63.5	42.8	41.6	46.6	74.0	47.8	63.7	53.2	58.0	9.3%
Fuel Total	94.5	81.6	89.7	83.8	112.5	80.8	108.0	90.6	95.3	
Electricity	25.3	37.9	25.5	41.7	36.6	24.1	33.2	30.5	34.5	9.3%
Total	119.8	119.5	115.2	125.5	149.1	105.0	141.2	121.2	129.9	
Aggregate Energy Consumption (toe: tons oil equivalent)										
Frewood+Charcoal	28,749	35,475	37,738	23,409	30,814	58,007	24,036	238,227	142,482	
Other fuel	58,959	39,194	32,692	29,323	59,178	84,053	34,546	337,945	221,199	
Fuel Total	87,707	74,669	70,429	52,731	89,992	142,061	58,582	576,171	**363,681**	
Electricity	23,497	34,669	20,021	26,234	29,270	42,394	18,012	194,098	131,683	
Total	111,205	109,338	90,450	78,965	119,262	184,455	76,594	770,269	**495,364**	

Source: JICA Study Team

d. Total Fuel Demand

Aggregating the fuel demand projection as explained above, future fuel demand at objective cities are summarized in Table 5.5-7. In 2018, the total fuel consumption is estimated to be 371 ktoe for the seven cities and 259 ktoe for the five cities. However, it goes down significantly if the fuel consumed at cement and lime factories at Tanga is excluded. The rest of the demand is estimated to be 152 tonnes per year in LNG equivalent in 2018. It will increase to 254 tonnes LNG equivalent in 2025 and 390 tonnes in LNG equivalent in 2030. This calculation provides us with attractive quantities. However, it should be noted that these numbers represent the situation wherein the fuel consumption is fully switched to natural gas. This is not realistic for considering a green field project.

Table 5.5-7 Aggregate Fuel Demand

	Arusha	Dodoma	Mbeya	Morogoro	Moshi	Mwanza	Tanga	Total	**5 cities**
【2018】	toe	toe	toe	toe	toe	toe	toe	toe	toe
Industry	1,300	4,500	500	10,200	1,700	17,700	79,600	115,500	97,300
Excluding cement and lime factories in Tanga							2,600	38,500	20,300
Services	400	300	400	300	400	700	200	2,700	1,600
Household	32,200	33,900	38,200	25,600	41,300	54,600	26,900	252,700	159,900
Total	33,900	38700	39100	36100	43400	73000	106,700	370,900	**258,800**
Excluding cement and lime factories in Tanga							29,700	293,900	181,800
LNG equivalent	**28,400**	**32,400**	**32,800**	**30,200**	**36,400**	**61,200**	89,400	310,700	216,800
Excluding cement and lime factories in Tanga							**24,900**	246,300	**152,300**
【2025】									
Industry	2,000	6,800	800	15,400	2,500	26,800	120,600	174,900	147,300
Excluding cement and lime factories in Tanga							3,900	58,200	30,600
Commercial/Public	5,400	3,400	2,800	3,200	4,200	5,400	2,100	26,500	18,300
Household	57,000	54,500	53,900	38,300	63,600	93,100	41,300	401,700	254,700
Total	64,400	64700	57500	56900	70300	125300	164,000	603,100	**420,300**
Excluding cement and lime factories in Tanga							47,300	486,400	303,600
LNG equivalent	**54,000**	**54,200**	**48,200**	**47,700**	**58,900**	**105,000**	137,400	505,300	352,100
Excluding cement and lime factories in Tanga							**39,600**	407,600	**254,400**
【2030】	toe	toe	toe	toe	toe	toe	toe	toe	toe
Industry	2,500	8,500	1,000	19,100	3,100	33,200	149,500	216,900	182,700
Excluding cement and lime factories in Tanga							4,800	72,200	38,000
Commercial/Public	15,800	14,900	13,100	10,800	13,700	28,300	9,100	105,700	64,300
Household	87,700	74,700	70,400	52,700	90,000	142,100	58,600	576,200	363,700
Total	106,000	98100	84500	82600	106800	203600	217,200	898,800	**610,700**
Excluding cement and lime factories in Tanga							72,500	754,100	466,000
LNG equivalent	**88,800**	**82,200**	**70,800**	**69,200**	**89,500**	**170,600**	182,000	753,000	511,600
Excluding cement and lime factories in Tanga							**60,700**	631,800	**390,400**

Source: JICA Study Team

5.5.2 Practical Gas Demand Based on REDS

Natural gas demand practically expected for the gas supply system may be composed of two types of users to whom gas will be delivered as follows;

a. General small users who receive gas from a local piped city gas system;

b. Large users who can receive gas from a city gas system as well as by bulk transport with tank trucks or bulk containers.

Construction of a city gas system can be considered only for the densely populated areas to keep the delivery pipeline cost per user within a reasonable range. In rural areas, pipeline distance will be longer while users along a pipeline are scarce. As a first approach, we investigate the cities covered by the REDS to examine if there is enough demand for the city gas system. In the interviews many people expressed their desire to switch to gas at an early opportunity. However, the upfront pipe connecting cost is expensive; only richer users can afford to pay it in the reality.

For the first project, therefore, we can consider only some part of the fuel consumption as the potential demand for switching to city gas.

Thus, we estimate the potential gas demand assuming the potential gas switching ratio for each sector as follows:

a. Industry: 70%
b. Commercial and public sector: 30%
c. Household sector: 20%

For the Group-A five cities as candidate for the model project, the aggregate potential gas demand will be 65,300 tonnes LNG equivalent for 2025 and 99,400 tonnes LNG equivalent for 2030. However, this assumes that local city gas systems will be developed simultaneously in all cities. It would be somewhat too ambitious to assume so before any city gas project is implemented successfully. Instead, the first local city gas project as a model project may be implemented at one city among them. Then, the demand size comes down to a range of 10-20 thousand tonnes a year.

Table 5.5-8 Fuel Demand Considering Gas Switching Potential

	Gas Switching	Arusha	Dodoma	Mbeya	Morogoro	Moshi	Mwanza	Tanga	Total	**5 cities**
【2025】										
Industry	**70%**	1,400	4,800	600	10,800	1,800	18,800	84,400	122,600	103,200
Excluding cement and lime factories in Tanga								2,700	40,900	21,500
Commercial/Public	**30%**	1,600	1,000	800	1,000	1,300	1,600	600	7,900	5,500
Household	**20%**	11,400	10,900	10,800	7,700	12,700	18,600	8,300	80,400	51,000
Total		14,400	16700	12200	19500	15800	39000	93,300	210,900	159,700
Excluding cement and lime factories in Tanga								11,600	129,200	78,000
LNG equivalent		**12,100**	**14,000**	**10,200**	**16,300**	**13,200**	**32,700**	**78,200**	176,700	**133,800**
Excluding cement and lime factories in Tanga								**9,700**	108,200	**65,300**
【2030】										
Industry	**70%**	1,800	6,000	700	13,400	2,200	23,200	104,700	152,000	128,100
Excluding cement and lime factories in Tanga								3,400	50,700	26,800
Commercial/Public	**30%**	4,700	4,500	3,900	3,200	4,100	8,500	2,700	31,600	19,200
Household	**20%**	17,500	14,900	14,100	10,500	18,000	28,400	11,700	115,100	72,600
Total		24,000	25,400	18,700	27,100	24,300	60,100	119,100	298,700	219,900
Excluding cement and lime factories in Tanga								17,800	197,400	118,600
LNG equivalent		**20,100**	**21,300**	**15,700**	**22,700**	**20,400**	**50,400**	**99,800**	250,200	**184,200**
Excluding cement and lime factories in Tanga								**14,900**	165,400	**99,400**

Source: JICA Study Team

In addition to this, users for direct bulk transport of natural gas located outside of the city gas coverage areas may be considered. As large users for bulk transport requiring a dedicated receiving system, users who consume fuel more than 20 tonnes oil equivalent per month are considered. In the Japanese market, users who use LNG more than one cargo of 12-15 tonnes are considered as potential bulk customers.

To estimate the size of such potential demand, it is assumed that 70% of the large users as listed in Table 5.5-3 and one-half of the services sector as picked up in Table 5.5-8 may switch to natural gas. The outcome is summarised in Table 5.5-9; the total gas demand in the five Group-A cities for direct bulk transport will be 17,500 tonnes LNG equivalent for 2025 and 28,800 tonnes LNG equivalent for 2030.

Table 5.5-9 Potential Gas Demand for Direct Bulk Transport

	Gas Switching	Arusha	Dodoma	Mbeya	Morogoro	Moshi	Mwanza	Tanga	Total	**5 cities**
【2025】		toe	toe	toe	toe	toe	toe	toe	toe	toe
Industry	70%	900	4,700	600	10,700	600	18,500	82,800	118,800	99,700
Excluding cement and lime factories in Tanga								1,100	37,100	18,000
LNG equivalent		800	3,900	500	9,000	500	15,500	69,400	99,600	**83,600**
Excluding cement and lime factories in Tanga								900	31,100	**15,100**
Commercial/Public	15%	800	500	400	500	700	800	300	4,000	2,800
LNG equivalent		700	400	300	400	600	700	300	3,400	**2,400**
Total: LNG equivalent tons		**1,500**	**4,300**	**800**	**9,400**	**1,100**	**16,200**	**69,700**	103,000	86,000
Excluding cement and lime factories in Tanga								**1,200**	34,500	**17,500**
【2030】										
Industry	70%	1,200	6,300	700	14,300	900	24,700	110,900	159,000	133,600
Excluding cement and lime factories in Tanga								1,600	49,700	24,300
LNG equivalent		1,000	5,300	600	12,000	800	20,700	92,900	133,300	**112,000**
Excluding cement and lime factories in Tanga								1,300	41,700	**20,400**
Commercial/Public	15%	2,400	2,300	2,000	1,600	2,100	4,300	1,400	16,100	9,800
LNG equivalent		2,000	1,900	1,700	1,300	1,800	3,600	1,200	13,500	**8,200**
Total: LNG equivalent tons		**3,000**	**7,200**	**2,300**	**13,300**	**2,600**	**24,300**	**94,100**	146,800	120,200
Excluding cement and lime factories in Tanga								**2,700**	55,400	**28,800**

Source: JICA Study Team

5.6 Supplemental Analysis: Demand Reading from Google Map

Potential city gas demand developed in Section 5.5 is projected based on the Regional Energy Demand Survey (REDS) conducted in 2018. The survey provides valuable information on the energy consumption pattern in the object cities, but there are several deficiencies such as below:

a. City gas system can be developed only in the areas with concentrated demand having dense distribution of residences, business/commercial buildings, public facilities, and factories. However, the REDS does not provide areal distribution of demand.

b. The REDS is a sample survey. It does not show the aggregate demand. In addition, there is a possibility that important energy users would be missing.

c. The REDS was conducted for seven major cities, namely, Dodoma, Morogoro, Tanga, Moshi, Arusha, Mwanza, and Mbeya. In other areas, also, fuel demand of certain concentration or independent large energy users may exist.

To make up for the above, the Study Team conducted a survey to assess the potential demand for LNG-based virtual pipeline reading the satellite images of the Google Map. The Study Team picked up 42 cities, towns and communities along the five (5) main land transport routes except for Dar es Salaam and the southern coastal regions where a gas pipeline is already built, as follows.

1) Central Corridor: 12 cities and towns from Kibaha to Dodoma
2) Northern coastal corridor: 7 cities and towns from Bagamoyo to Tanga

3) North East Corridor: 8 cities and towns from Korogwe to Arusha
4) Great North Corridor: 9 cities and towns beyond Dodoma through to the Lake regions
5) TANZAM Corridor: 6 cities and towns beyond Morogoro through to Mbeya

Source: JICA Study Team work on Google Map

Figure 5.6-1 Distribution of Major Markets along Corridors

For assessment of fuel demand for city gas system, candidate areas with densely built houses are enclosed from the satellite image, size of these areas is calculated and number of houses are counted with simple assumptions. Assuming that an average family member is 5 and gas consumption is 200 kg per year, residential fuel demand is estimated. For business/commercial demand, schools, hospitals, hotels, business and government offices and public facilities are picked up. For industrial demand, factories are picked up. From this information and the information of the REDS, fuel demand is estimated assuming certain ratios to the residential demand. The detail outcome of this assessment is summarised in Appendix-A.

Table 5.6-1 Potential Demand for City Gas at Selected Cities and Towns

	Region	City/Town	Elevation	Distance from DSM	City Gas Coverage			Gas Demand				
					Area	Houses	Population	Residential	Biz/Com	Industry	Total	(rounded)
Central Corridor			m	km	ha			t	t	t	t	t
12	Pwani	Kibaha	130	30	1600	7000	35000	1400	70	140	1610	1600
		Kibaha West	140	35	2,800	10,100	50,500	2020	60	100	2180	2200
		Visiga	130	55	300	1,300	6,500	260	10	10	280	300
		Mlandizi	70	60	1,400	7,400	37,000	1480	40	0	1520	1500
		Chalinze	210	100	300	1,300	6,500	260	10	0	270	300
	Morogoro	Morogoro	510	185	12200	52800	264000	10560	1060	5280	16900	16900
		Kilosa	490	280	600	2,300	11,500	460	20	0	480	500
		Dakawa	360	230	50	300	1,500	60	0	0	60	100
	Dodoma	Dumila	430	250	600	2,200	11,000	440	10	0	450	500
		Gairo	1290	315	500	2,000	10,000	400	10	0	410	400
		Chamwino	1100	415	200	1,000	5,000	200	10	0	210	200
		Dodoma	1140	440	15700	45500	227500	9100	1820	910	11830	11800
	Total				36,250	133,200	666,000	26,640	3,120	6,440	36,200	36,300
Northern Coastal Corridori and DSM Periphery												
7	Pwani	Bagamoyo	20	80	1300	5700	28500	1140	60	0	1200	1,200
		Kisarawe	220	15	100	600	3,000	120	0	0	120	100
		Msata	260	140	100	600	3,000	120	0	0	120	100
	Tanga	Serega	310	275	200	1,100	5,500	220	0	0	220	200
		Handeni	700	270	1,600	9,500	47,500	1,900	40	0	1,940	1,900
		Muheza	200	310	2,400	9,600	48,000	1,920	40	0	1,960	2,000
		Tanga	20	350	3,400	22,000	110,000	4,400	440	660	5,500	5,500
	Total				9,100	49,100	245,500	9,820	580	660	11,060	11,000
North East Corridor												
8	Tanga	Koroge	310	300	1,600	8,700	43,500	1,740	30	0	1,770	1,800
		Mombo	440	340	200	1,200	6,000	240	0	0	240	200
	Kilimanjaro	Same	850	455	400	1,900	9,500	380	20	0	400	400
		Mwanga	920	510	600	2,100	10,500	420	10	0	430	400
		Himo	800	540	500	4,100	20,500	820	40	0	860	900
		Moshi	850	560	5,900	20,400	102,000	4,080	410	1,220	5,710	5,700
		Ng'ombe	940	590	1,400	5,700	28,500	1,140	30	0	1,170	1,200
	Arusha	Arusha	1,400	640	14,600	57,400	287,000	11,480	1,150	1,720	14,350	14,400
	Total				25,200	101,500	507,500	20,300	1,690	2,940	24,930	25,000
Great North Corridor												
9	Singida	Singida	1510	690	2,500	8,000	40,000	1,600	80	80	1,760	1,800
	Shinyanga	Shinyanga	1130	970	4,300	12,300	61,500	2,460	50	120	2,630	2,600
		Kahama	1220	975	5,200	21,600	108,000	4,320	90	0	4,410	4,400
	Geita	Geita	1250	1100	3,800	15,900	79,500	3,180	60	0	3,240	3,200
	Mwanza	Mwanza	1150	1130	13,500	86,000	430,000	17,200	860	2,580	20,640	20,600
	Mara	Musoma	1140	1140/1250	2,500	15,600	78,000	3,120	90	160	3,370	3,400
	Kagera	Bukoba	1140	1370	2,400	13,700	68,500	2,740	80	50	2,870	2,900
	Tabora	Tabora	1200	820	5,800	32,000	160,000	6,400	130	640	7,170	7,200
	Kigoma	Kigoma	890	1240	7,800	44,300	221,500	8,860	180	0	9,040	9,000
	Total				47,800	249,400	1,247,000	49,880	1,620	3,630	55,130	55,100
TANZAM Crridor												
6	Morogoro	Iringa	1640	490	2,600	17,100	85,500	3,420	170	340	3,930	3,900
	Njombe	Makambako	1680	650	2,400	11,600	58,000	2,320	120	120	2,560	2,600
		Njombe	1920	710	2,400	11,100	55,500	2,220	110	0	2,330	2,300
	Mbeya	Mbeya	1150	940/1070	7,200	27,600	138,000	5,520	280	0	5,800	5,800
	Rukwa	Sumbawanga	1710	820	8,800	40,800	204,000	8,160	410	1,220	9,790	9,800
	Songea	Songea	1840	1140	4,900	12,500	62,500	2,500	130	0	2,630	2,600
	Total				28,300	120,700	603,500	24,140	1,220	1,680	27,040	27,000
42												
Total					146,650	653,900	3,269,500	130,780	8,230	15,350	154,360	154,400

In addition to the regional assessment, individual industrial users are listed as shown in Appendix-B. Compared with business/commercial sector, energy consumption per facility is much bigger in manufacturing and mining sectors. Some of them even though isolated can be users for LNG bulk delivery. For example, there are many mines for gold, diamond and Tanzanite on the highland. Fuel to drive off-road vehicles and power generators (electricity is used to drive ore crushing, milling machines, and general equipment) would be switched to LNG. A cluster of factories can form an integrated gas system that can aggregate even small users.

The outcome of the overall demand assessment is summarized in Table 5.6-1. These are estimates of the present fuel consumption but do no include any future plan. The table shows only a rough estimation with many arbitrary assumptions. In particular, it is difficult to read from the satellite image such crucial information on feature of business at buildings and energy consumption profiles at factories. We need more direct survey to know these. Nevertheless, the table shows us more information on energy consumption beyond the REDS.

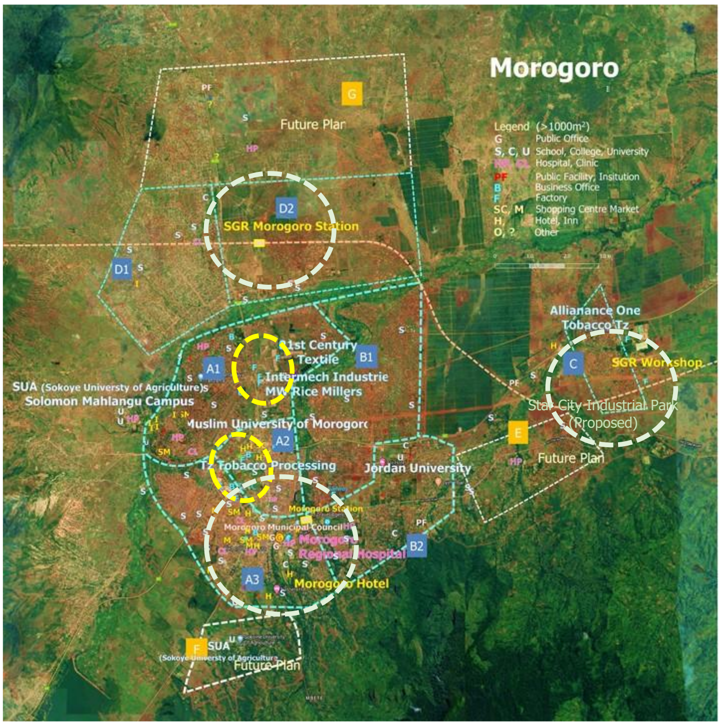
Important findings from this assessment are as follows:

a. The aggregate fuel consumption as potential gas demand in the north-eastern regions along the Central, Northern Coastal and North East Corridors is estimated to be 54,100 tons a year or 155 tons per day x 350 days in LNG equivalent.

b. Among them residential demand is only 40,000 tons a year. Unit consumption per residence is small and the demand may build up slowly as it takes time to develop the delivery network.

c. Industrial demand is only 10,000 tons excluding intensive energy users such as cement and limestone industries. Industrial activities are expected to expand in Tanzania, but their development plans are not known from the satellite images.

d. Factories are located closely to each other, mostly in the designated industrial areas, and close to the city centre.



Source: JICA Study Team work on Google Map

Figure 5.6-2 Morogoro City

For example, Figure 5.6-2 shows distribution of factories and demand centres in Morogoro. Major functions of the city are developed around Morogoro station of the TRC Central Line and factories are placed at outskirts of this area. But these areas are relatively close. Now SGR Morogoro station is being built in the northern area of the city. This area is presently empty but substantial development is expected with opening of the SGR service. In addition, in the east of the city near the SGR workshop and Alliance One Tobacco plant, construction of the Morogoro Dry Port and development of Star City Industrial Park is being discussed.

In addition to the above, it is known from the REDS 2018 that electricity consumption is relatively large compared with fuel consumption at these factories.

Table 5.6-2 Industrial Users in Morogoro and Their Energy Consumption

	Regional Energy Demand Survey 2018	Monthly Fuel Consumption (excluding use for transport)								
		GSL	DGO	HFO	LPG	Coal	Chacoal	FW/Res	Electricity	
		kL	kL	kL	t	t	t	t	MWH	kW
A	21 Century Textiles Limited				1.6	900?	0.3		16	35
A	TPM(1998) LTD		0.5						484	1,075
A	Mazava Fablic & Production E.A.L.		2.8						124	275
A	Intermech Engineering		0.0						0	1
A	MW Rice Millers									
B	Tanzania Tobacco Processors Limited		17.5	206					814	1,808
B	Agriculture Seeds Agency		7.1						1	2
B	Inernational Tanfeeds Ltd									
C	Alliance One Tobacco Tanzania		11.5	79	38.0				688	1,529
C	Mambo Coffee Company									
C	Star City Industrial Park (plan)									

(Note) 1,000 kW of electricity consumption translates to 80 tons per month of LNG consumption.
Fuel consumption data were collected by the Regional Energy Demand Survey 2018.

From the above observations, we can consider the following hypothesis:

1) Industrial demand with relatively large energy consumption can provide a core demand for city gas development. Number of them is small and their decision making may be faster which helps enhance project formulation.

2) Factories may be grouped as a cluster for integrated natural gas supply via District Gas System integrated including small fuel users.

3) Electricity consumption is relatively large at factories. If District Energy System is applicable, heat and power can be supplied to them with a high energy efficiency at 70% or above. Electricity will be supplied by its own generator and its cooling water and exhaust gas can be heat-exchanged for hot water and steam. Taking up the electricity demand at the industrial park, greater energy demand can be produced compared with simple supply of natural gas. If appropriate, electricity can also be supplied to the grid.

4) In addition, though a unique challenge, the cryogenic heat of LNG can be used to run warehouses for frozen and cold storage and to produce dry ice (frozen CO_2) and ice cubes. These will improve production conditions at meat, fish and food processing plants and contribute to creation of cold supply chain.

District Energy System with CHP

1. Electricity is common and dominant energy required at industrial parks.
2. Taking-up electricity (5-10MW++), combined greater energy demand will be created.
3. Auto-producer plant offers stable and secure electricity at high efficiency.

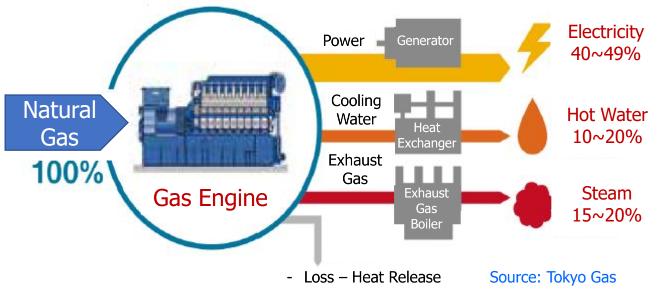


Figure 5.6-3 Efficiency of District Energy System

Plausibility of the above hypothetical scenarios is crucial to establish a tangible mini-LNG project. To confirm this, credible information should be collected directly from potential industrial users together with their future plans and preference on energy selection. To this end, it is necessary to conduct market survey; that is, to interview major industrial players and city development planners and obtain such information, their comments and intentions.

5.7 Market Research on Regional Energy Demand

(This section is withheld because of confidential information.)

The above market research gives us an image of the gas system we are aiming at. Nevertheless, the assessment is yet fragile. Sweet areas preferred for early stage of city gas development would be limited as discussed in Section 5.5 and 5.6. To establish a credible gas sales plan, many issues need to be sort out through deliberate discussion and policy setting. Despite the challenging work in front, we believe this report is an important milestone to step forward to the National Gas Development Plan.

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Chapter 6 Introduction of Natural Gas Vehicles

As an experimental CNG supply project is being implemented in Dar es Salaam, natural gas is not yet popular as automotive fuel in Tanzania. If natural gas supply system is established widely, it will be possible to expand use of natural gas vehicles (NGVs) countrywide. Although initial hurdles are high, introduction of NGVs will bring multiple benefits for Tanzania; to reduce foreign currency outflow, enhance development of domestic gas industry and reduce GHG emissions.

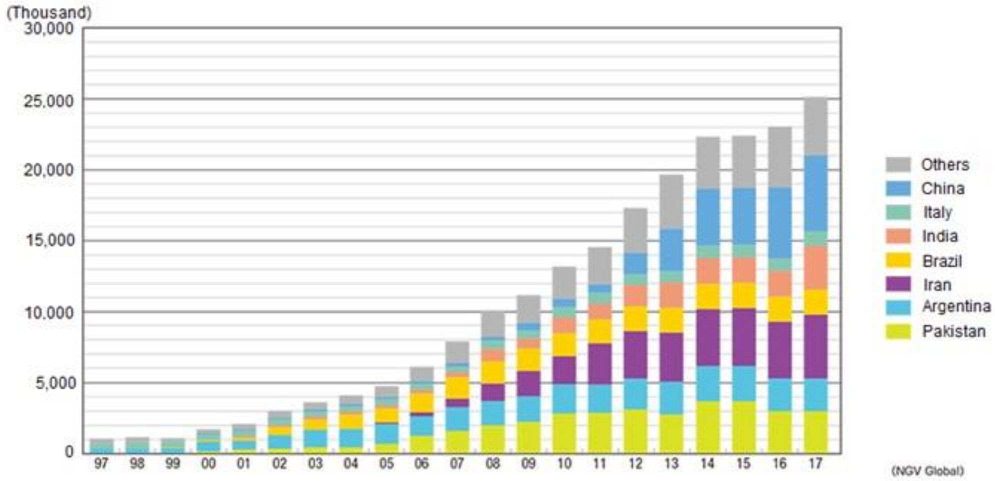
6.1 Global Trends of Natural Gas Vehicles and Gas Consumption

6.1.1 Whole the World

Natural gas is widely used as motor fuel mainly in those countries where indigenous gas is available at a affordable price. NGVs are welcomed as environment friendly vehicles with low emissions of pollutants. There are about 26 million NGVs and 30 thousand natural gas filling stations worldwide and they are increasing fast. Leading countries with more than one million units of NGVs are China, Iran, Pakistan, Argentine, India and Brazil. NGVs mostly use compressed natural gas (CNG), while LNG is getting popular in recent years.

Source: The Japan Gas Association/ NGV Global

Figure 6.1-1 World NGV Map (2017)



Source: The Japan Gas Association/ NGV Global

Figure 6.1-2 World Penetration of NGV

Number of NGVs and Natural Gas Stations by area as of the end of December 2019 is shown in the table below.

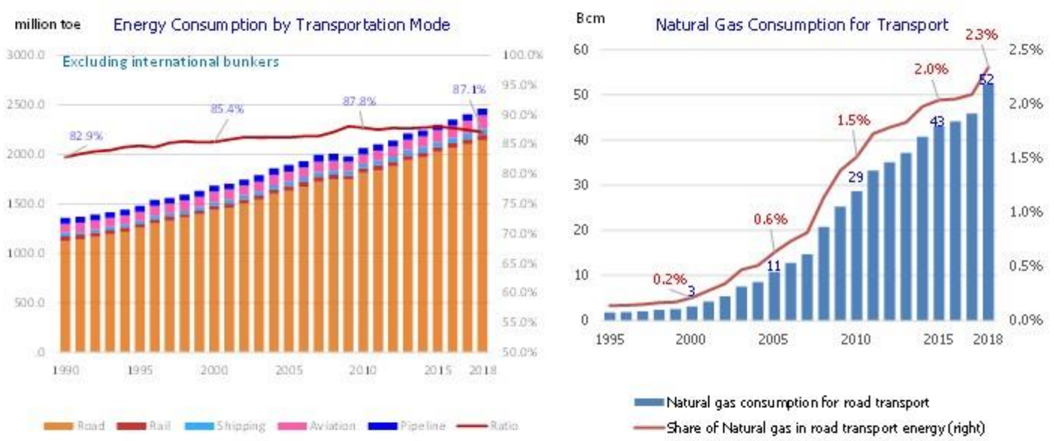
Table 6.1-1 Number of NGVs and Natural Gas Stations by Area (December 2019)

Area	Number of NGV	Number of NG Station
Asia, Pacific	20,473,673	20,275
Europe	2,062,621	5,194
North America	224,500	1,856
Latin Amrica	5,484,676	5,848
Africa	295,349	210
Total	28,540,819	33,383

Source: NGV Global

As shown in Figure 6.1-2, NGVs started to increase around the turn of the century. It gained momentum with oil price hike in 2005-2010, shale gas revolution in 2010-2015 and rising concern on air quality in emerging countries in particular in China and India. Natural gas consumption for road transport has increased robust, although its share among the road transport energy is still small at approximately 2% in 2016.

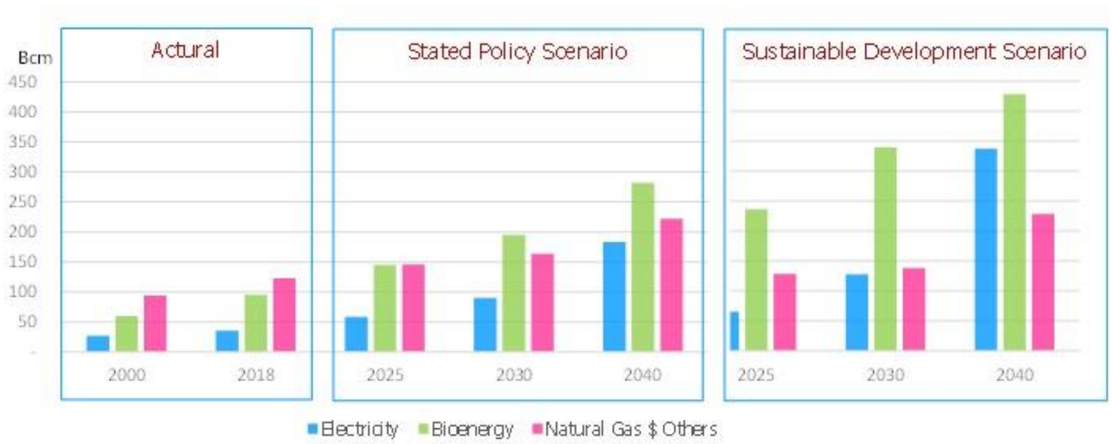
The IEA projects in its World Energy Outlook 2018 that the transport sector natural gas consumption continues to increase in coming decades. It represents the gas consumption of all transport sub-sectors. Among them, the amount used for pipeline transport comprises approximately 60% of the transport sector gas consumption.



出所：IEA World Energy Balances 2020

Figure 6.1-3 Natural Gas Consumption for Road Transport

Natural gas demand for transport nearly doubles under the New Policy Scenario from 123 Bcm in 2018 to 222 Bcm in 2040 mainly because of the policy driven efforts in China to promote use of CNG and LNG. LNG is also being introduced in the marine transport sector because of the regulation on the sulphur content to be implemented by the International Maritime Organisation (IMO) from 2020. The gas consumption for transport will be further driven up to 228 Mtoe in 2040 under the Sustainable Development Scenario where use of emission-intensive fuels will be severely controlled.



Note：IEA WEO 2020 classifies “Natural Gas and Others” as one item , where “Others” include coal used for railway and shipping comprising nearly 0.04% of the item for 2018.

Source：IEA World Energy Outlook 2020

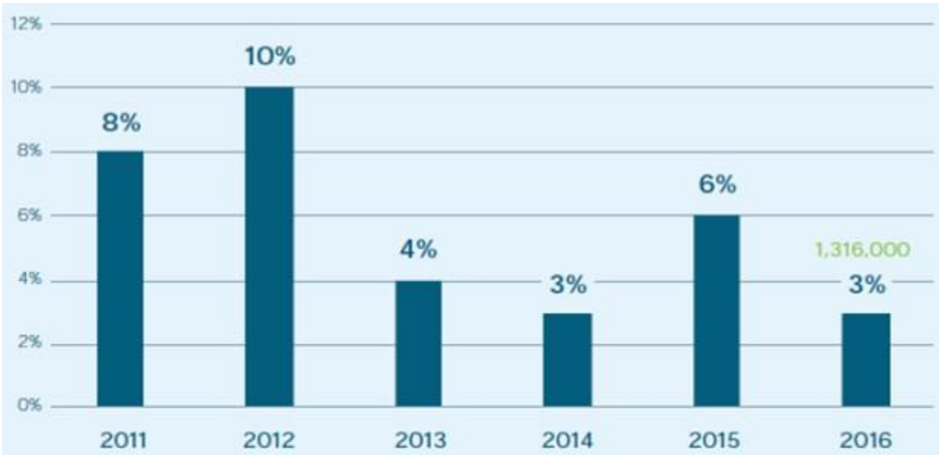
Figure 6.1-4 World Natural Gas Demand Outlook for Transport Sector

However, the 2020 projection shows a substantial setback from the 2018 version where natural gas used for transportation was projected to reach 408 BCM in 2040. It anticipates that strong headwind caused by the drop in oil prices due to the demand reduction by the COVID 19 pandemic and recent strong promotion policy for introduction of EVs[41]. As shown in the Figure 6.1-4, under the IEA's SDS, electricity consumption for EVs will increase greatly and overtake natural gas after 2030.

In the following sections, we will look into the present status of NGV penetration in major regions and countries such as Europe, US, China and India. The background and historical development of NGV introduction will be analysed for India.

6.1.2 Europe

Number of NGVs in Europe increased 3% in 2016 and reached 1,316,000. As shown in Figure 6.1-5, the average annual growth rate since 2011 was 5.6%, but it slightly decreased in 2016.



Source：NGV Europe

Figure 6.1-5 Growth Rate of NGVs in EU and EFTA Total

On the other hand, the number of natural gas stations (CNG and LNG) increased almost 18% per annum between 2015 and 2017. As CNG stations increased 16%, LNG stations increased 94% in the same period. The share of LNG stations over the total natural gas stations was only 3% in 2017, but it reached 8% in February 2021. Changes in numbers of gas stations are summarized in Table 6.1-2.

Table 6.1-2 Numbers of Natural Gas Stations in Europe

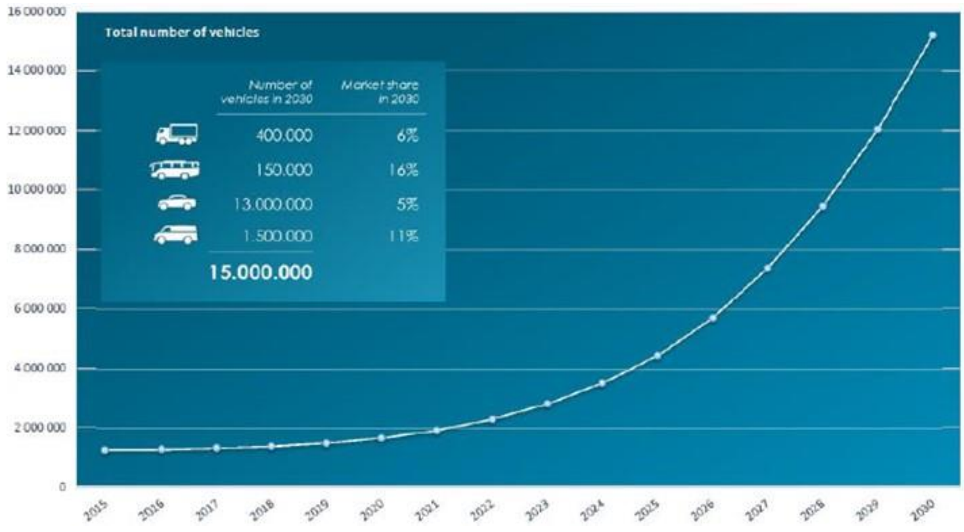
Fuel	2015	2016	2017	Feb. 2021
CNG	2,842	2,997	3,600	3,940
LNG	52	58	101	364
Total	2,894	3,055	3,701	4,304

Source：NGVA Europe

[41] World Energy Outlook 2020, IEA

Though the share of NGVs in total vehicle production in Europe is small, the market is featured with various models of NGVs supplied. In 2017, on the OEM (Original Equipment Manufactured) basis, there were 26 models for passenger cars, 15 models for light commercial vehicles, 9 models for trucks, and 15 models for buses supplied in the market. Number of NGV trucks (mainly LNG trucks) is still small. However, its market is being expanded as procurement of LNG is getting easier with increases in import of LNG and LNG service stations. NGV trucks are expected to penetrate further as various promotion policies will be enforced according to the European Alternative Fuel Infrastructure Directive (Directive 94/2014/EU, DAFI).

Figure 6.1-6 shows the NGV outlook projected by NGVA Europe, which envisages that the number of NGVs will reach 15 million by 2030. Number of natural gas stations (CNG and LNG) will also increase by 3,800.



Source：NGVA Europe

Figure 6.1-6 Outlook of NGVs in Europe

EU is promoting use of alternative fuels in the transport sector in order to reduce emissions of air pollutants and GHGs. To this end, DAFI was issued aiming at construction of supply infrastructure for alternative fuels such as natural gas (CNG and LNG), biomethane, electricity, hydrogen, etc. The Directive requests member countries to formulate National Policy Frameworks (NPF) that envisages implementation, and to set out construction schedule of CNG supply infrastructure in urban areas by 2020, and construction schedule of CNG and LNG supply infrastructure along the Trans-European Network for Transport (TEN-T) by 2025.

It is estimated that construction of alternative fuels supply infrastructure in EU will require investment of 5.2 billion € by 2020 and 16-20 € by in 2025. To this end, financial support will be provided by Connecting Europe Facility (CEF), Horizon 2020 and European Fund for Strategic Investments (ESFI).

Experimental Project of constructing LNG station infrastructure: LNG Blue Corridors

In order to accumulate important knowledge (know-how and experiences of the industry and stakeholders) with regards to LNG transport and infrastructure technology, LNG Blue Corridors Project was implemented from May 2013 through April 2017 (completed in May 2018) . Producers of heavy duty vehicles, fuel supply companies, fuel sale companies and transport companies participated in the project and they pursued simple and cost-effective way of LNG supply for road transport.

Source：NGVA Europe

Figure 6.1-7 LNG Stations in Europe as at February 2021

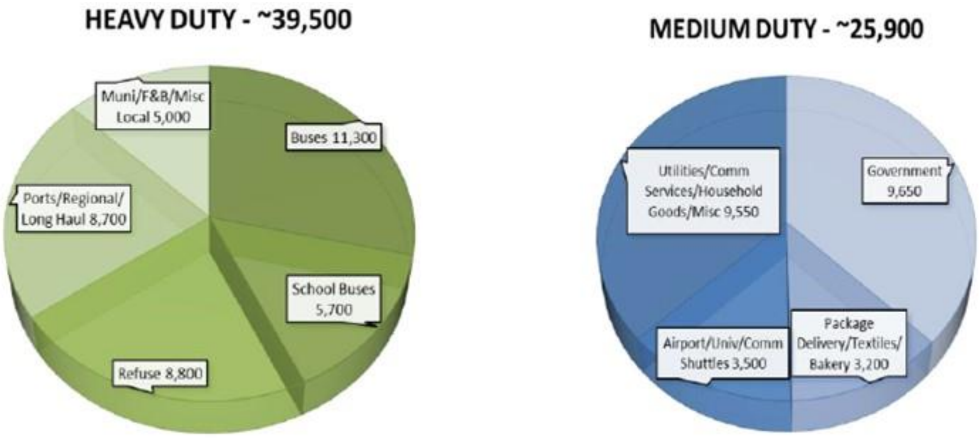
This project aims to verify the following points.

- If LNG, the first candidate of alternative fuel, can duly replace diesel oil in the future.
- To implement a 3 years verification test using 100 Dual Fuel Heavy Duty Vehicles, constructing 14 new LNG stations at strategic points along the 4 main routes (Mediterranean, Atlantic, West/East, and North/South)
- Aiming at carbon neutral, to implement test of LBM (Liquefied Bio Methane) produced from wastes and liquefied

Figure 6.1-7 shows distribution of LNG stations as at February 2021.

6.1.3 US

In 2017, there were 260 million vehicles running in the US; while most of them were using petroleum fuel and NGVs were only 150-160 thousand units. Among the NGVs, light duty vehicles were 55%, buses 15% and heavy duty trucks 15%. Figure 6.1-8 shows distribution of medium and heavy duty NGVs.



Source：Clean Fuels Consulting

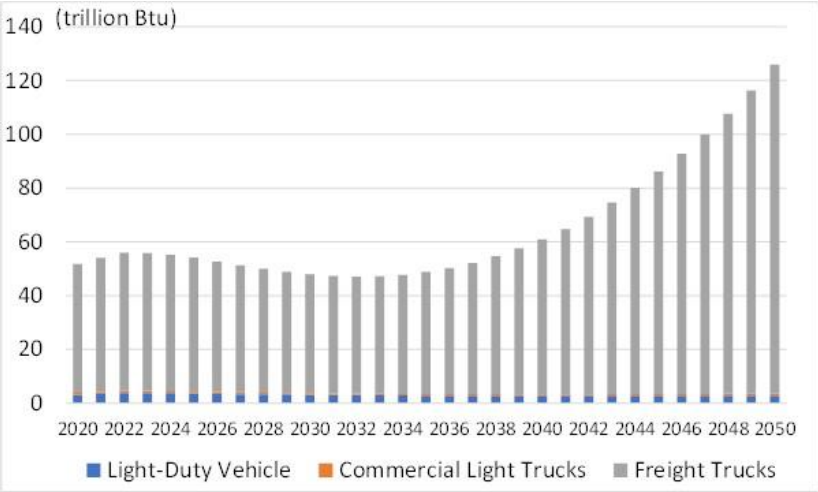
Figure 6.1-8 Distribution of Medium and Heavy Duty NGVs in US

As at February 2021, there were 1,680 CNG stations and plans for 50 stations in the US. Among them, LNG stations were 144 with additional 38 plans. Figure 6.1-9 shows distribution of natural gas stations. LNG stations are relatively dominant in California.

Source：NGV America

Figure 6.1-9 Natural Gas Stations in US

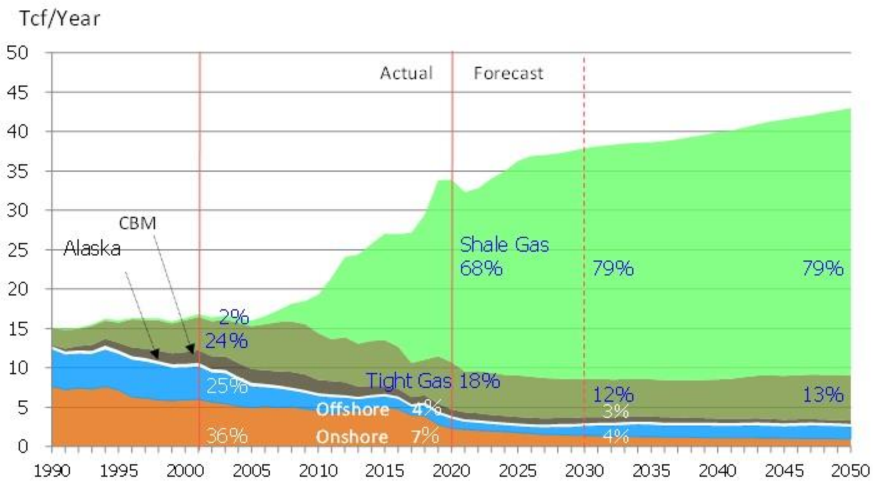
Since 1992, the US Government has promoted introduction of NGVs and AFVs (Alternative Fuel Vehicles) by way of tax break, premiums and market based incentive policies. However, there are issues such that incentives are available only for short periods at maximum 3 years, and that the parliament is not successful to set out effective national policy to promote AFV market. Apart from these approaches by the federal government, there are 22 states providing incentives such as grant, rebate, soft loan and preferential taxation.



Source：Annual Energy Outlook 2021, EIA

Figure 6.1-10 Outlook of Natural Gas Demand by Road Transportation in US

Figure 6.1-10 shows outlook of natural gas consumption (CNG and LNG) for road transport in the reference case developed in the Annual Energy Outlook (AEO) announced by the USEIA in February 2021. According to the AEO 2021, gas consumption for road transport will increase from 48.0 trillion BTU in 2020 to 51.3 trillion BTU in 2023, but then start to decrease and reach 43.5 trillion BTU in 2032. After that, however, it will restart to increase and reach 122.4 trillion BTU in 2050 which is 2.6 times that of 2020. Share of natural gas among the energy consumption for road transport will evolve from 0.3% in 2020 to 0.6% in 2050. By mode of use, natural gas consumption for freight trucks comprises over 90% of natural gas for road transport and will reach 97% in 2050. As envisaged here, freight trucks will drive natural gas use for transport, and use of LNG rather than CNG will increase along with growing size of freight trucks.



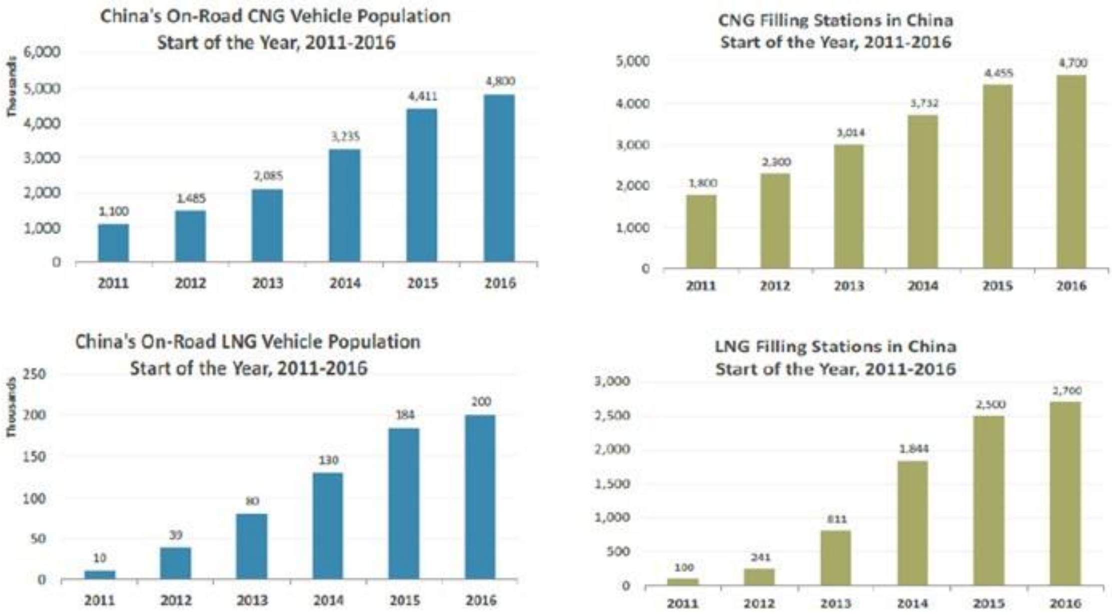
Source：Annual Energy Outlook 2021, EIA

Figure 6.1-11 Outlook of Natural Gas Production in US

As the background of increase in natural gas consumption as transport fuel, there was increase of natural gas production in the US. It has increased greatly since the 2010s, which was brought by production increase of unconventional natural gas such as shale gas and tight gas. Figure 6.1-11 shows natural gas production outlook for the Reference Case of AEO 2021. The share of shale gas and tight gas combined reached 68% in 2020, and it will further increase to 79% in 2030.

6.1.4 China

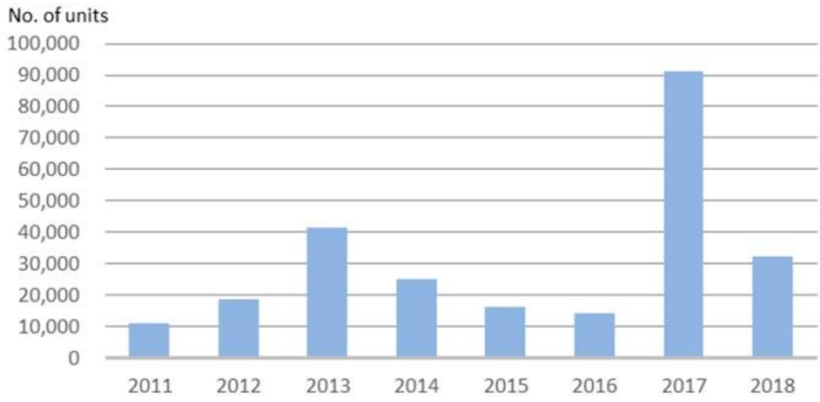
Figure 6.1-12 shows numbers of CNG vehicles and CNG stations in China. In 2016, there were 4,411,000 CNG vehicles and 200,000 LNG vehicles, 4,700 CNG stations and 2,700 LNG stations.



Source：27th World Gas Conference, IGU, June 2018

Figure 6.1-12 Number of NGVs and Natural Gas Stations in China

Compared with the US and European markets, Chinese market is featured with a large number of LNG vehicles, in particular LNG trucks. Evolution of LNG truck sales is shown in Figure 6.1-13. In China, sale of LNG vehicles increased greatly in 2017. This was represented by the abrupt increase in sale of heavy duty trucks (HDTs) which expanded 500%. However, it shrunk extremely next year. It was caused by the LNG price increase due to serious gas supply shortage incurred by the strong coal-to-gas switching policy implemented during the 2017-2018 winter. Purchase of LNG vehicles were held off in the market, accordingly.

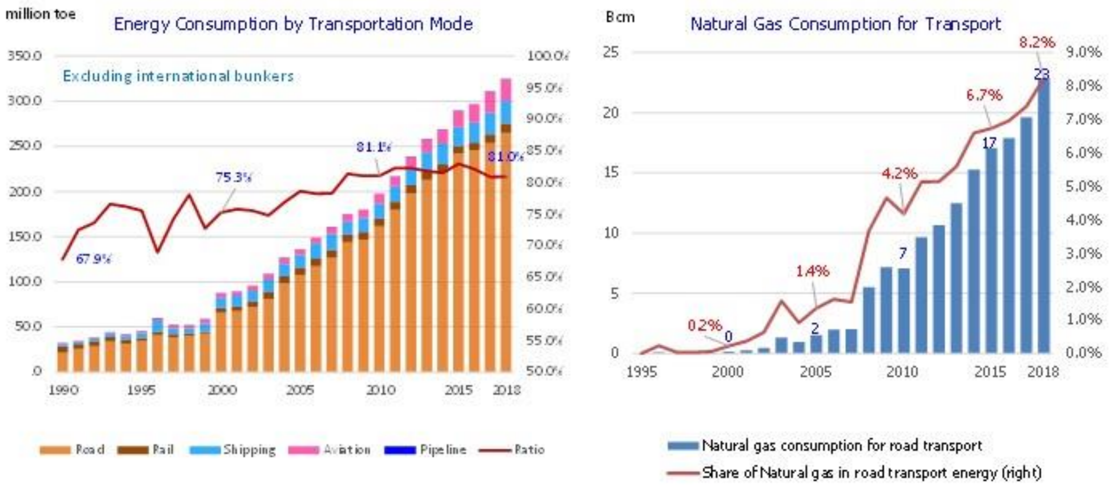


Source：19th International Conference & Exhibition on Liquefied Natural Gas

Figure 6.1-13 LNG Truck Sales in China

As at the end of 2018, there were 343,933 LNG vehicles of 70% of which were 236,265 were LNG HDTs, and the rest were LNG buses. There were 2,528 LNG stations at the end of 2017, and 2,552 at the end of 2018 in China. LNG are supplied to these stations from mini-LNG supply bases in interior areas and LNG import terminals along the coast.

As explained above, there are many NGVs used in China and natural gas consumption for transportation is increasing rapidly. According to the IEA statistics, natural gas use for transport fuel started in 1996 in China. Evolution of natural gas consumption for the sector is shown in Figure 6.1-14. Natural gas consumption has shown rapid increase since the late 2000s, and the share of natural gas used for road transport increased from 1% in the early 2000s to 8.2% in 2018.



Source：World Energy Balances 2020, IEA

Figure 6.1-14 Natural Gas Demand for Road Transportation in China

Background of Natural Gas Use for Transport

During the 1950s, there is various researches were implemented in China to explore for alternative motor fuels to cope with oil supply shortage. As a big gas field was found in Sichuan province in 1958 and associated gas production also started at many oil fields, people began trial use of natural gas as motor fuel. In Sichuan and Henan provinces, natural gas was packed in bags and used as fuel for buses. Natural gas was easily available at a reasonable price; $0.98/MMBtu in 1987. Problems were its limited driving distance per one filling due to low energy intensity when natural gas is used as it is (at a low pressure), and concerns on safety.

Therefore, they started use of natural gas in the form of CNG and LNG. At first, vehicles used dual-fuel system with oil, and finally shifted to use only CNG or LNG. Technical research on use of LNG for motor vehicle began 1961, however use of LNG as motor fuel started abrupt increase only in 2008 when use of LNG was recommended by the National High-Tech R&D Program (2008-2010) under the 11th Five Year Plan. As the backdrop, LNG import in China started in 2006 and also LNG supply from interior gas fields in Xinjiang provinces started to truck transport to Guangdong province; these activities paved the way to expand LNG use. In 2010 piped natural gas import from Central Asian countries started and national oil companies were trying to create new gas demand in the areas other than city gas or power generation.

Drivers for Use of LNG as Transport Fuel

In the background of expanding use of LNG as transport fuel, there are several preferential drivers in China as follows.

- Cost Competitiveness of LNG

Main driver for increasing sale of LNG vehicles is the price differential with diesel oil. In particular, Heavy Duty Vehicles for industry and commercial use are sensitive to fuel price. In China, several reviews have been implemental to date on natural gas pricing differential and market regulation, however LNG is still price-competitive to diesel oil.

- Promotion and Incentive Policies

In the 12th Five Year Plan and after, use of CNG and LNG in the transport sector has been enhanced as a part of low-carbonization policy and majors to cope with air pollution in urban areas. Many provincial and municipal governments provide subsidies for buses and taxis for use of CNG and LNG.

- Availability of Gas and LNG

During the 2017-2018 winter when gas supply shortage was caused by the abrupt coal-to-gas switching policy, the Chinese Government ordered priority supply of gas for home heating. As a result, domestic LNG price went up and seriously impacted the large LNG vehicles market. However, upon this incident, Chinese Government implemented fundamental consolidation of the natural gas supply sectors of national oil companies to resolve anticipation of extreme gas supply shortage (See Chapter 2). After this, sale of large LNG vehicles became active again.

- Gas Infrastructure

When a new market is being created, there is always a syndrome regarding which one of demand or infrastructure be created first. In the transport fuel sector, development of LNG stations is the key for expansion of LNG HDT sale. In China, competitive price of LNG and national promotion policy implemented in 2012-2014 encouraged investments for LNG stations; during 2012-2014, LNG stations increased three-fold. As LNG vehicles increased greatly, sale of LNG at these stations also increased and the payback period of the investment became substantially shorter. This trend was also enhanced by the fact that, reflecting demand increase, firm position was established on technology and pricing LNG trucks.

6.1.5 India

Today, India is implementing a strong campaign to switch motor fuel to natural gas and has successfully introduced more than 3 million units of natural gas vehicles (NGVs). India started introduction of NGVs in relatively early days waged by serious concern on the air quality in its capital. This section will review the history and current status of NGV introduction in India.

1. Turning point of introducing CNG in India

Compressed natural gas (CNG) was introduced with three CNG stations in Delhi in 1993, but the number of NGVs remained limited through the 1990s. The turning point was the Supreme Court Order made in 1998 relating to the prevailing severe air pollution.

In 1998, the Supreme Court ordered the Government that all buses, three-wheelers and taxis should be replaced to CNG by April 2001 constructing 70 CNG filling stations simultaneously introducing financial incentives to convert vehicles from conventional fuels to CNG.

However, the vehicle industry stood against it. Finally, in 2002, the Supreme Court imposed the Government penalty for the reason of wasting time and a daily penalty on each diesel bus running. By December 2002, diesel busses had disappeared from Delhi.

At that time, cost of converting a diesel bus to a CNG bus was;

a. To purchase a new CNG bus: US$32,000,
b. To replace the engine of the existing bus: US$14,000,
c. To convert the diesel engine of the existing bus to CNG: US$8,000

As number of NGVs grow, incidents on safety, such as buses catching fire, occurred due to inferior quality of conversion and maintenance work. Experiencing these, a new regulation on the CNG safety was enforced.

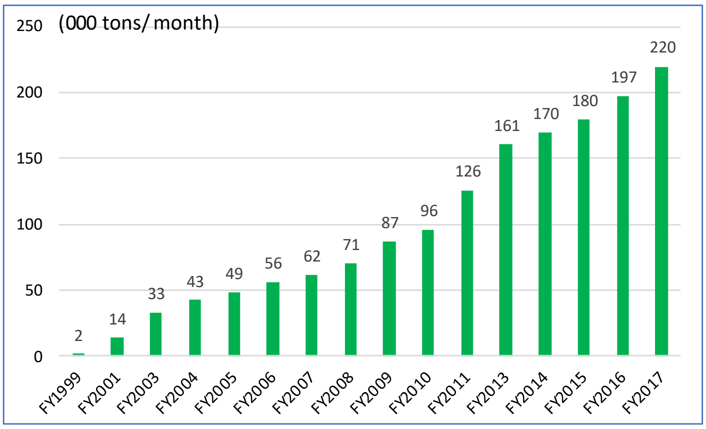
2. CNG Promotion Policy by the Government

To date, Ministry of Petroleum and Natural Gas (MoPNG) has created New Initiatives for the City Gas Distribution (CGD) sector including promotion of CNG as follows:

a. Ordering replacement of costly and polluting fuels with natural gas.
b. Mandating CNG vehicles in various cities (e.g. Delhi and Mumbai).
c. Constructing CGD infrastructure in Smart-Cities.
d. Nominating a greater number of cities by Petroleum and Natural Gas Regulatory Board (PNGRB) for development of City Gas Distribution (CGD) network.
e. 100% allocation of domestic gas for the domestic piped natural gas (PNG) and CNG segments for faster roll out of PNG connections and CNG stations in given City/Geographical Areas.
f. Enhancing development of gas infrastructure in the eastern part of the country.

3. Growth of CNG

Figure 6.1-15 shows the CNG sales in India. CNG sales has increased from two thousand tons per month in FY2000 to 220 thousand tons/ month in FY2017. Looking at annual growth rates, FY2000 to FY2010 was 46%, FY2010 to FY2017 was 12%, and FY2000 to FY2017 was 30%.



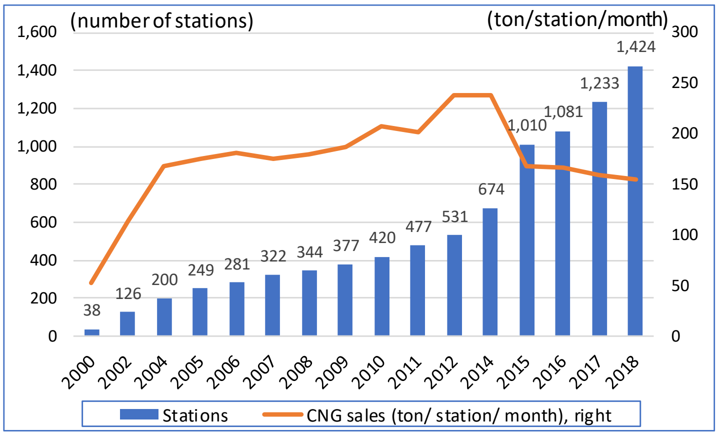
Note; FY2000, FY2002 and FY2012: Lack of information, FY: Fiscal Year (from April to March in India)

Source; TERI Energy Data Directory and Yearbook and Indian Petroleum & Natural Gas Statistics

Figure 6.1-15 CNG sales in India

Figure 6.1-16 shows the number of CNG stations at the end of every March and monthly CNG sales by station in India. The number of CNG stations increased from 38 in 2000 to 1,424 in 2018. Annual growth rate was 27% from 2000 to 2010, 16% from 2010 to 2018 and 22% from 2000 to 2018.

CNG sales by station increased from 52 tons/month in 2000 to 238 tons/month in 2014 however, decreased 154 tons/month in 2018.



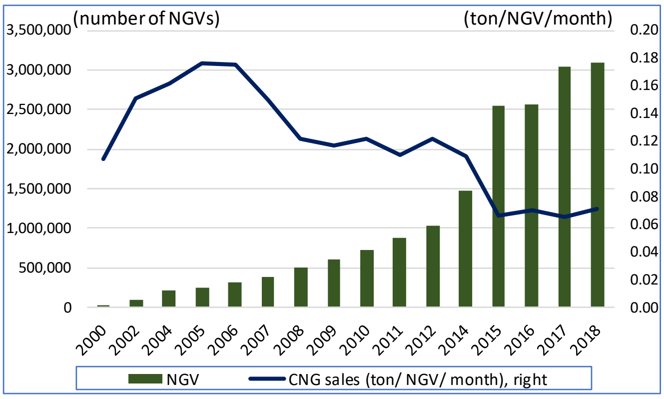
Note; FY2000, FY2002 and FY2012: Lack of information

Source; TERI Energy Data Directory and Yearbook and Indian Petroleum & Natural Gas Statistics

Figure 6.1-16 Number of CNG stations in India

Figure 6.1-17 shows the number of NGVs at the end of every March and monthly CNG sales by station in India. The number of NGVs increased from 18,067 in 2000 to 3,090,139 in 2018. Annual growth rate was 44% from 2000 to 2010, 20% from 2010 to 2018 and 33% from 2000 to 2018.

CNG sales per NGV station increased from 0.11 tons/month in 2000 to 0.18 tons/month in 2006, however, it decreased 0.07 tons/month in 2018. This may be due to increase of small NGVs after conversion of the first batch of heavy vehicles has completed.



Note; FY2000, FY2002 and FY2012: Lack of information

Source; TERI Energy Data Directory and Yearbook and Indian Petroleum & Natural Gas Statistics

Figure 6.1-17 Number of NGVs in India

6.2 Motor Vehicles and Natural Gas Demand in Tanzania

The number of motor vehicles in Tanzania is estimated to be about 2.5 million units in 2018, more than a half of which are motorbikes and tricycles. The penetration ratio is about 50 units per 1,000 persons. Motorization is yet at its dawn, but it may develop fast. Particularly, motorbikes, light passenger vehicles (LPV) and light goods vehicles (LGV) are thought to increase as analysed in Section 6.1.2 Increase of trucks and buses will be modest compared with them. However, Tanzania being a vast continental country, they will bear an important role in development of passenger and freight transport. Heavy duty vehicles will consume a large amount of fuel despite their small population. The number of motor vehicles is projected to exceed 3 million units around 2020-2022, 5 million units around 2030 and 8 million around 2040. The penetration speed may fluctuate greatly according to the country's economic development pattern in coming decades.

Suppose that NGVs will be introduced at around 2025 and its proportion will increase progressively, natural gas consumption will increase slowly in the early stage but will accelerate the growing speed from around 2030 as the vehicle ownership itself will pick-up when peoples' income exceeds certain threshold. Natural gas will be introduced to tricycles, LPV/LGVs and heavy vehicles such as buses and trucks. The trial projection is made according to the macro projection of the transport sector explained in Section 6.1.2 and applying the following assumptions:

a. Natural gas driven tricycles are popular in Asian countries such as India, Pakistan and Thailand serving as taxicab. We assume relatively early penetration to reach 15% by 2030, 40% by 2040 and 50% by 2040.
b. On other vehicles, we assume relatively conservative penetration ratios, 0.1% for 2025, 3% for 2030, 10% for 2040 and 20% for 2050.

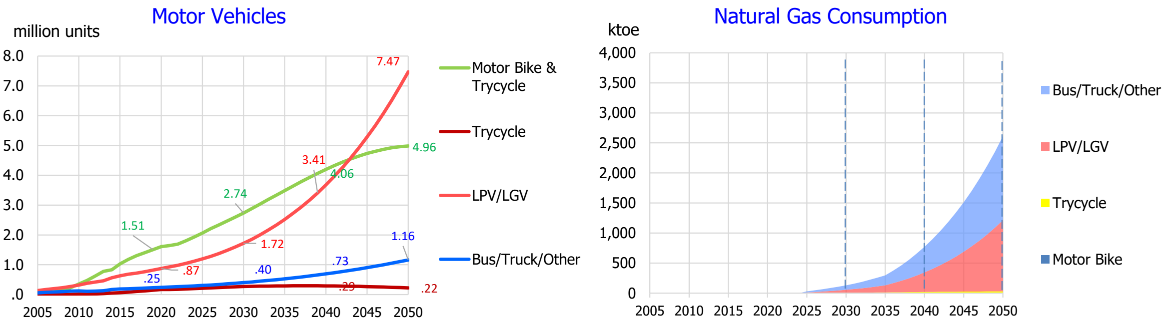
Under the above scenario, number of natural gas vehicles reaches 100,000 units in 2030 and then start inflating fast. It will expand almost 5 times between 2030 and 2040, and more than double between 2040 and 2050. Although this projection is based on many bold assumptions, it indicates a great possibility of natural gas vehicles.

Table 6.2-1 Growth of Natural Gas Vehicles

	Vehicles (1,000 units)					NGV Ratio					NGVs (1,000 units)				
	Motor bike	Tricycle	LPV/ LGV	Truck/ Bus/etc.	Total	Motor bike	Tricycle	LPV/ LGV	Truck/ Bus/etc.	Total	Motor bike	Tricycle	LPV/ LGV	Truck/ Bus/etc.	Total
2015	1,027	63	632	186	**1,908**	0.0%	0.0%	0.0%	0.0%	**0.0%**	0	0	0	0	**0**
2020	1,606	169	874	242	**2,803**	0.0%	0.0%	0.0%	0.0%	**0.0%**	0	0	0	0	**0**
2025	2,061	211	1,195	305	**3,603**	0.0%	0.5%	0.1%	0.1%	**0.1%**	0	1	1	0	**3**
2030	2,737	272	1,719	401	**4,820**	0.0%	15.0%	3.0%	3.0%	**2.2%**	0	41	52	12	**104**
2035	3,489	292	2,521	529	**6,352**	0.0%	30.0%	5.0%	5.0%	**3.8%**	0	88	126	26	**240**
2040	4,197	292	3,675	694	**8,198**	0.0%	40.0%	10.0%	10.0%	**6.8%**	0	117	368	69	**554**
2045	4,732	268	5,285	903	**10,368**	0.0%	45.0%	15.0%	15.0%	**10.1%**	0	121	793	135	**1,049**
2050	4,985	223	7,473	1,162	**12,907**	0.0%	50.0%	20.0%	20.0%	**14.2%**	0	111	1,495	232	**1,838**

Table 6.2-2 Natural Gas Demand as Motor Fuel

	NGVs				Annual Fuel Use			Natural Gas Consumption				
	Tricycle	LPV/ LGV	Truck/ Bus/etc.	Total	Tricycle	LPV/ LGV	Truck/ Bus/etc.	Tricycle	LPV/ LGV	Truck/ Bus/etc.	Total	LNG Equivalent
	(thousand units)				(liter per year per unit)			(thousand tons oil equivalent)				ktons
2015	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	2	12	3	17	12	3	17	0	12	19	32	24
2030	41	52	12	104	52	12	104	6	50	76	132	102
2035	88	126	26	240	126	26	240	14	117	165	296	228
2040	146	368	69	583	368	69	583	26	324	428	779	599
2045	134	793	135	1,062	793	135	1,062	30	662	824	1,516	1,166
2050	111	1,495	232	1,838	1,495	232	1,838	32	1,184	1,395	2,611	2,008



Source: JICA Study Team

Figure 6.2-1 Motor Vehicles and Natural Gas Consumption

Applying annual fuel consumption per vehicle, natural gas demand as motor fuel is projected in Table 6.2-2. According to this calculation, the amount of petroleum products to be replaced by natural gas will exceed 132,000 toe or 102,000tons LNG equivalent by 2030, and 800,000 toe or 600,000 tons LNG equivalent by 2040. It starts slowly but grows into a substantial quantity in a decade or so. Fuel for tricycles remain least as they are fuel efficient. On the other hand, while the number of heavy vehicles is not so big, their energy consumption is large. Tanzania being a large continental country, developing long haul transport system with stable fuel supply is an important policy objective to support its economic growth.

Introducing NGVs is not an easy task. A lot of upfront arrangement must be made coherently to prepare such as natural gas supply system, vehicle conversion services, laws and regulations on technology, safety, environment, and economic conditions. The speed of NGV penetration depends on how proactive policies will be developed on energy, environment and transport calling for close collaboration of relevant authorities and strong support of the government.

6.3 Feature of Natural Gas as Motor Fuel and Technical Issues

6.3.1 Feature of Natural Gas as Motor Fuel

Natural gas is usable for most of transport devices such as motorbike, tricycle, passenger car, van, forklift, bus, truck, railway, ship, etc. NGVs are environment friendly; for example, LNG/CNG trucks emit 10% less carbon dioxide compared with diesel oil. Both CNG and LNG can be used as motor fuel. However, there are substantial differences between them with regard to fuel supply system, storage tank, fuel charging system and safety system, and hence big differences in vehicle prices and fuel costs.

In case gas is supplied by pipe via city gas system, CNG can be supplied installing a compressor at a filling station. However, CNG is inferior in its driving distance compared to petrol and diesel oil. CNG is kept at a high pressure of 20-25 MPa in tubed type fuel tanks, and vehicle’s drive distance is usually less than 300 km (maximum 500 km on an express way). Therefore, CNG is mainly used for routine services such as in house service (forklift), commuter bus, parcel delivery and waste collection.

On the other hand, LNG is kept in liquid status in fuel tank at a pressure of 0.3-1.0 MPa and vehicle driving distance is considerably longer compared with CNG, for example 1,000 km. However, it is necessary to liquify natural gas at a filling station or deliver LNG there. In recent years, technologies on small scale LNG have made great progress, and today it is commercially possible to use combination of small scale LNG plant, LNG truck and/or container transport. In the US and Europe, construction of LNG filling stations is developing fast targeting at supply for long distance freight trucks.

As will be explained in Chapter 10, in case LNG is supplied as gas source, both LNG and CNG can be supplied at a filling station. Thus, L-CNG type filling station can serve every type of natural gas for vehicles. LNG is stored at an ambient pressure but creates high pressure when vaporised. Because of this, it is economically superior to CNG that needs pressure-up of city gas by a high pressure compressor.

To use natural gas as a fuel, vehicles must be equipped with specific engine and fuel tank. Used cars need conversion of these, while such cost is not so expensive for gasoline driven cars.

6.3.2 Technical Issues for Introduction of Natural Gas Vehicles

Existing vehicles using liquid fuel can be converted to natural gas vehicles by replacing its engine. Therefore, natural gas has been used as a motor fuel since early times. In this section, we look into technical issues of NGVs for freight transport.

(1) CNG and LNG

Natural gas is mainly composed of methane. To use methane as transport fuel, it is necessary to keep it in a compact fuel tank(s) by way of CNG or LNG. Both CNG and LNG are used being kept in fuel cylinder(s) on the vehicle, where CNG is kept in gaseous status in cylinders at a high pressure of 20-30 MPa, while LNG is kept in liquid status at an ambient pressure but extremely cooled at -162℃. CNG tank is heavy being designed to withstand a high pressure.

Presently, LNG is used mainly for trucks. LNG trucks need cryogenic cylinder(s) to keep LNG at an extremely low temperature and avoid boil-off of methane in the tank. Boil-off of methane makes density of LNG higher (heavier). This causes change of ignition timing, abnormal burning (knocking) and eventually hurt the engine. Usually boil-off starts within 5 days when LNG is kept in a tank. Therefore, it is necessary to manage operation of LNG trucks under close collaboration of operators and cargo owners.

In relation to boil-off, it is desirable that LNG has a high Methane Number (MN, pure methane = 100). As Tanzanian natural gas is composed of more than 99% of methane, specification change of LNG by boil-off remains quite limited.

Compared with diesel oil, density of CNG is lower and its volume loaded on a vehicle will be greater at maximum 6 times. Energy density of LNG is much higher than that of CNG. Nevertheless, the volume of LNG will be almost double of diesel oil to cover the same distance.

Selection of CNG or LNG as NGV fuel depends on size and purpose of the vehicle. LNG is used by vehicles for large size and long distance transport (annual driving distance exceeding 100,000 km). However, because of the risk of boil-off gas (BOG), they should be trucks operated on regular routine and time schedule. CNG is preferable for passenger cars and smaller trucks for non-regular and short distance.

(2) Natural Gas Station

1) CNG Station

There are two types of CNG stations as below.

(a) Slow Filling

Gas at low-pressure is supplied from city gas piping to a CNG station, compressed to a high-pressure by a compressor and filled into a gas cylinder equipped on a vehicle. This system takes time for filling, but compressors are used effectively as they are operated constantly giving higher efficiency with least deterioration. Such stations are usually adopted for self-owned truck stations and gas is filled during night time.

(b) Quick Filling

This system is suitable for a truck station along a trunk line with heavy traffic as gas filling is made in a short time. At such a station, natural gas supplied from city gas system is kept at a high-pressure so that they can fill quickly. CNG is supplied at around 30 MPa, however 20% of the available space in the storage tank is not usable due to rising temperature during compression. Therefore, such station needs strong compressors and storage tubes and hence greater investment and higher operation cost compared with slow filling stations.

2) LNG Station

Fuel filling time for an LNG truck is similar to that for gasoline and diesel oil. However, an LNG station needs special complex equipment such as a cryogenic tank, cooling system, safety system to avoid high-pressure at an LNG storage tank, etc. LNG is supplied directly from an LNG plant or an import terminal. LNG truck drivers must receive training on safe loading/unloading of LNG; this would incur an incremental cost.

(3) Conversion of Engine

There are two types of ignition methods for engines, namely spark plug ignition and compression ignition.

Spark plug ignition system is same that for gasoline vehicles, uses 100% natural gas, and loaded on smaller vehicles.

Compression ignition system uses diesel oil as the ignition source[42]. For compression ignition system, there are Dual Fuel type and High Pressure Direct Injection (HPDI) type engines, and both of them can be applied for conversion from diesel oil use. Both systems can use either CNG or LNG.

Table 6.3-1 Spark Plug Ignition and Compression Ignition

Ignition Method	Engine Technology	Natural Gas Ratio	Application	Conversion
Plug Ignition	Regular type	100%	Light Vehicles (Gasoline Type)	Easy
Plug Ignition	Lean Burn	100%	Light Vehicles (Gasoline Type)	Easy
Compression Ignition	Dual Fuel	NG:50~70% + Diesel	Heavy Viehilce (Diesel type)	Possible, high cost
Compression Ignition	High Pressure Direct Injection	NG:95% + Diesel	Heavy Viehilce (Diesel type)	Possible, high efficiency

Source: JICA Study teams

1) In Dual Fuel system, natural gas is pre-mixed with diesel oil and put into the engine, diesel oil ignites by compression, and natural gas burns simultaneously. Such vehicle can run only on diesel oil after natural gas is finished.

2) In HPDI system, high pressure gas at 25 MPa is injected into the piston cylinder where diesel oil is burning by compression. This system is able to utilise low quality gases.

It is technically possible to manufacture an engine that specifically uses methane only, but such engine is inflexible for fuel selection in the market.

(4) Methane Slip

Compared with gasoline and diesel oil, natural gas emits 20-30% lower CO_2 that is a source of global warming. However, NGVs have a problem of Methane Slip.

There are two types of engines; spark plug ignited Otto Cycle engines and compression ignited Diesel Cycle engines. By the Otto Cycle method, an appropriate amount of natural gas as fuel is pre-mixed with Combustion Air, injected into a cylinder, compressed and then burnt. In this process, the ratio of the pre-mixed gas fuel to the air is important. Due to the relative shortage of the air incurred during load-change, or pre-mixed gas hiding in the small gap in the piston ring, it is unavoidable that a part of fuel methane be released into the air without burning. This phenomenon is called as Methane Slip.

According to the IPCC 4th Report, GWP (Global Warming Potential) of methane is 25-fold of

[42] Natural ignition temperatures are 540℃ for methane, 280℃ for gasoline and 210℃ for diesel.

that of CO_2, namely, methane incurs 25 times greater global warming effect than CO_2. Therefore, even a small amount of methane leakage incurs material effect on global warming.

On the other hand, gas engine by Diesel Cycle uses a relatively large amount of compressed air injected just before burning of natural gas as fuel. In principle, therefore, methane leakage into the air without burning is rarely observed. In contrast, Methane Slip problem is anticipated converting engine to the Dual Fuel system.

(5) Conversion Technology

In countries where NGVs are widely used, conversion of gasoline driven vehicles to natural gas driven is quite common. There are many conversion kits available in many countries market, and service companies for gas conversion. However, when the technical learning level of the conversion service company is low, problems would occur so that mechanical troubles happen frequently and emissions of air pollutants increase.

In Japan, NGVs are mainly promoted by city gas companies. NGVs running in Japan are not those converted from gasoline vehicles, but designed specifically for natural gas use. This is because gasoline driven vehicles converted to natural gas use cannot clear the Japanese emissions regulations.

In India, there are many gas conversion kits domestically produced, and many workshops for conversion services. One of Japanese car makers began gas conversion business in India, but pulled out from it facing many claims raised on mechanical troubles by low-grade conversion service conducted by unexperienced non-affiliate conversion service companies.

6.4 Outlook and Issues of NGV Introduction for Tanzania

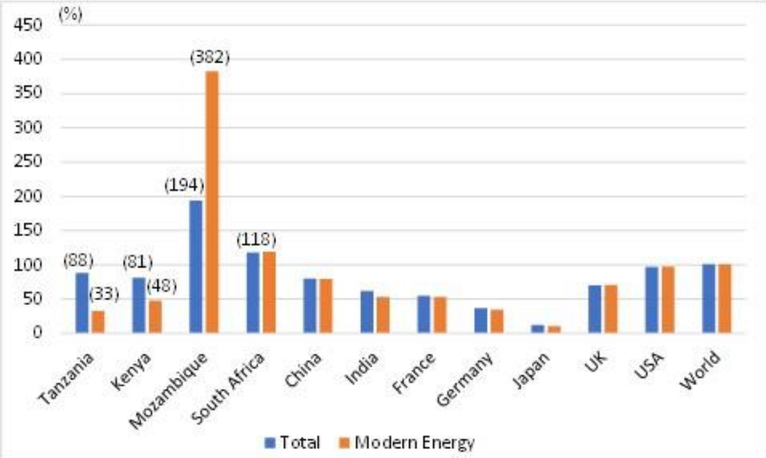
In this section, we look into introduction of NGVs in Tanzania in terms of energy security, trade balance, air pollution and global warming.

6.4.1 Energy Security

There are several points when we look into status of energy security for a country; among them, the most popular index is self-sufficiency of energy. Based on the IEA World Energy Balances 2020, energy sufficiency rates in 2018 for various countries are summarized in Figure 6.4-1. As energy sufficiency rates, we take up overall sufficiency rate and that of Modern Energy excluding primary solid biofuels such as firewood and charcoal. The overall energy sufficiency for Tanzania was 88% in 2018, while the self-sufficiency of Modern Energy was significantly lower at 33%. Looking to neighbouring countries, the overall energy sufficiency rate for Kenya was 81%, slightly lower than Tanzania, while that for Modern Energy was 48%, significantly higher than Tanzania. The latter is due to utilization of geothermal resources[43]. For Mozambique who

[43] The IEA Statistics assumes energy efficiency of geothermal at 10% and estimates the primary energy input for geothermal utilization by back calculation. In general, fuel efficiency of steam turbines for thermal power

produces and exports coal and natural gas, the self-sufficiency rates for both total energy and Modern energy exceed 100%.



Source: World Energy Balances 2020, IEA

Figure 6.4-1 Energy self-sufficiency rate in Major Countries and Regions in 2018

Table 6.4-1 summarises Modern Energy self-sufficiency rates in 2018 for 3 East African countries.

The self-sufficiency rate of oil for Tanzania is 0%, which is most used among energies, but its self-sufficiency would not rise unless oil discovery in the country. Presently, Tanzania depends 100% of oil consumption on import. In order to raise the self-sufficiency rate and reduce risks on energy security, it is effective to increase production and consumption of natural gas and so decrease oil consumption.

Table 6.4-1 Modern Energy self-sufficiency in 3 East African Countries in 2018

Unit: ktoe

Country	Description	Coal	Oil	Natural gas	Hydro	Geothermal	Others	Total
Tanzania	**Production**	**387**	**0**	**622**	**192**	**0**	**8**	**1,209**
	(Import)	(0)	(2,583)	(0)	-	-	(10)	(2,583)
	(Export)	(0)	(-144)	(0)	-	-	(0)	(-144)
	Primary Supply	**387**	**2,439**	**622**	**192**	**0**	**18**	**3,658**
	Self-sufficiency	100%	0%	100%	100%	-	44%	33%
Kenya	**Production**	**0**	**0**	**0**	**343**	**4,459**	**32**	**4,834**
	(Import)	(262)	(5,789)	(0)	-	-	(8)	(6,060)
	(Export)	(0)	(-791)	(0)	-	-	(-6)	(-797)
	Primary Supply	**262**	**4,998**	**0**	**343**	**4,459**	**34**	**10,096**
	Self-sufficiency	0%	0%	-	100%	100%	94%	48%
Mozambique	**Production**	**7,898**	**45**	**4,137**	**1,197**	**0**	**0**	**13,277**
	(Import)	(0)	(1,619)	(0)	-	-	(851)	(2,470)
	(Export)	(-8,449)	(-93)	(-3,418)	-	-	(-898)	(-12,858)
	Primary Supply	**33**	**1,572**	**719**	**1,197**	**0**	**-47**	**3,474**
	Self-sufficiency	23933%	3%	575%	100%	-	-	382%

Note: Others include Solar and Wind Power. Primary Supply includes stock change

Source: World Energy Balances 2020, IEA

generation are around 50% and hence IEA Statistics tends to overestimate the primary energy input by use of geothermal.

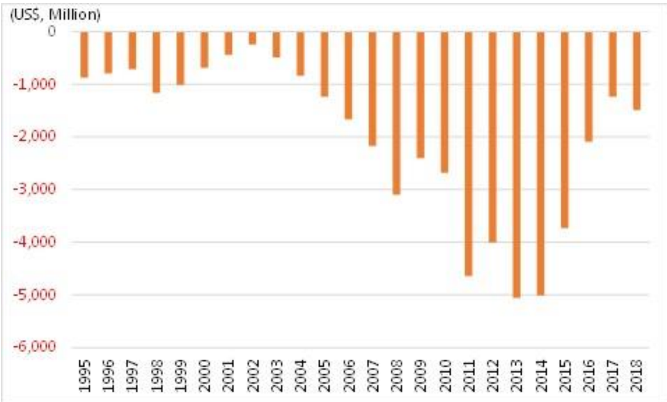
Kenya is not endowed with fossil energy resources but achieves a higher self-sufficiency rate utilising which domestic geothermal resources.

Among 3 East African Countries, Mozambique is endowed with fossil energy resources and keeps a high self-sufficiency by utilising them. It will be further enhanced once the Mozambique LNG project is materialised.

As Tanzania is endowed with natural gas resources, the country is able to improve its energy self-sufficiency greatly utilising natural gas resources. From the view point of energy security, it is an important policy option to increase production and consumption of natural gas by introducing NGVs and decrease consumption and import of oil products.

6.4.2 Net Trade Balance

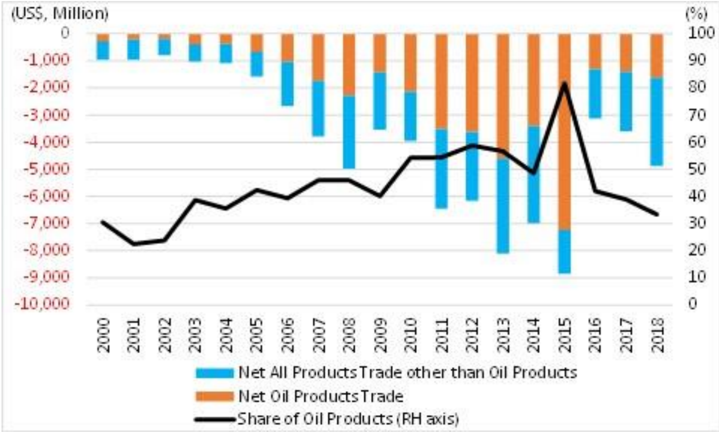
Figure 6.4-2 shows net trade balance of commodities and services for Tanzania. The country's trade balance has been kept in red constantly, and hence reduction of oil import will contribute to significant improvement of its trade deficit.



Source: Net trade in goods and services, World Bank, Last updated 2020/9/8

Figure 6.4-2 Net Trade Balance of Products and Services in Tanzania

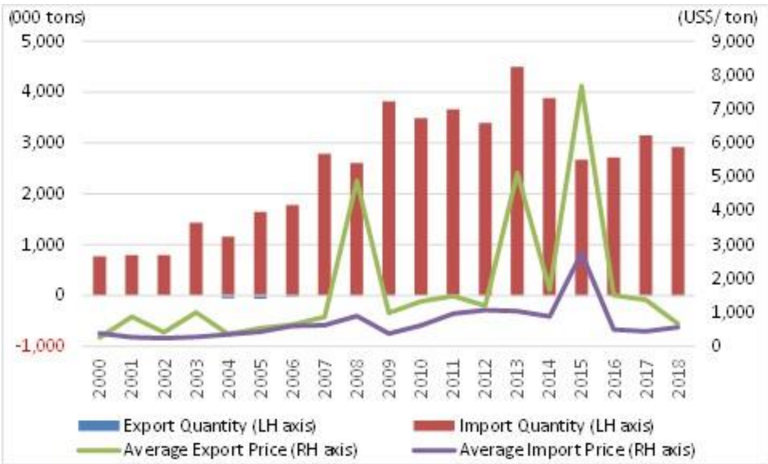
Though cited from different sources, net import amount of fuel and commodities (import – export, not including services) of Tanzania is shown in Figure 6.4-3. The share of petroleum product import over the net import of commodities is high and was 82% in 2015. Most of petroleum products are used as motor fuel. As the motor vehicles will increase greatly along with economic growth, import of petroleum products is anticipated to grow significantly. It is an urgent matter for Tanzania how to control the growing outflow of foreign currencies caused by increasing petroleum products import.



Source: World Integrated Trade Solution, World Bank

Figure 6.4-3 Net Import of Fuels and Others in Tanzania

Price volatility of petroleum products are high, and impacts the country's trade balance greatly. Import/export amount of petroleum products and their average prices are shown in Figure 6.4-4. According to the IEA Statistics, export of petroleum products is mainly bunker fuels for international services (airplanes and ships), and is deemed as semi-local consumption. Among the import quantity, diesel gas oil import for truck and bus is biggest followed by petrol for cars. Introducing NGVs and reducing oil import, it is possible to control the effect of price volatility of petroleum products to a considerable extent.



Source: World Integrated Trade Solution, World Bank

Figure 6.4-4 Import and Export and average price of Oil Products in Tanzania

In Section 6.6.4, relating to the outlook on vehicles and natural gas demand in Tanzania, it is estimated that petroleum products will be replaced by natural gas at 300,000 tonnes in 2030, and 1 million tonnes in 2040 (see Table 6.6-2). Translating these into monetary amount applying the average import price of fuels (\$560/ton) in 2018, it is calculated that import amount will be reduced by \$176 million in 2030, and \$581 million in 2040. These amounts are compared with net trade amounts of petroleum products and the total commodities in 2018 for Tanzania in Figure 6.4-2. Compared with the net petroleum trade amount in 2018, oil import amount will be reduced by 11% for 2030, and 36% for 2040.

Table 6.4-2 Reduction Ratio of Fuel Import Amount by Natural Gas Switching (Basis 2018)

	2018	2030	2040
Net Trade Value (2018) Net Oil Product Trade Net Total Product Trade	 -1,629 US$, Million -4,884 US$, Million		
Average Oil Product Import Price	560 US$/ ton		
Replaced Oil Product Imports		315 ktoe	1,038 ktoe
Replaced Oil Product Import Value On the basis of 2018 Average Oil Product Import Price		176 US$, Million	581 US$, Million
Impact for Net Trade Valeu On the basis of 2018 Net Oil Product Trade On the basis of 2018 Net Total Product Trade		 11 % 4 %	 36 % 12 %

Source: JICA Study Team

6.4.3 Air Pollution

Typical air pollutants are nitrogen oxides (NOx), sulfur oxides (SOx) and particulate matter (PM). Transportation sector highly depends on petroleum fuels and is the major emitter of air pollutants. According to the IEA, transportation sector emitted 54% of the global energy related NOx, 10% of SO_2 and 12% of PM2.5 in 2018[44].

1. Impact of Air Pollutants on Human Health and Environment

a) NOx

Major Sources

NOx is emitted into the air mainly due to fuel combustion. Major sources of NOx emissions are passenger cars, trucks, buses, power plants and offload vehicles.

Impacts on Human Health

In-take of high density NOx may stimulate organ of respiration. Short-period exposure would cause diseases of respiratory organs, worsen asthma, incur symptoms on respiratory organs (cough, wheezing, difficult breathing), hospitalization, emergency treatment, etc. Long time exposure to high-density NOx would cause asthma, and high sensitivities to respiratory incidents. In addition, NOx will react with chemical matters in the air and create both particulate matter and ozone. If taken, both of them impacts respiratory organs.

Impacts on Environment

NOx creates acid rain interacting with water, oxygen and other chemical matters in the air. Acid

[44] IEA World Energy Outlook 2019 Annex A

rain is dangerous to sensitive ecosystems in lakes and forests. And also, NOx creates mist of nitrates, and causes eutrophication in coastal water.

b) SOx

Major Sources

The biggest source of SOx is fossil fuel burning at power stations and factories. It is also exhausted by vehicles using high surfer fuels.

Impacts on Human Health

Even short time exposure to SOx would cause respiratory problems and difficult breathing. SO_2 causes severe symptoms of asthma, especially for children.

Dense SOx are released into the air would react with other chemical matters and create small Particulate Matter (PM). Such small particulate matter would be taken deep in lungs and heavy exposure would cause problems on human health.

Impacts on Environment

Dense SOx would hurt leaves of plants, reduces their growth and impacts vegetation.

SOx also causes acid rain that is dangerous to the ecosystem.

SOx, interactive with other chemical matters in the air, creates particulate matter and causes mist. And accumulation of particular matters on stones and other materials (including important cultural properties such as statues and monuments) would make them dirty and damaged.

c) PM

Major Sources

Most of particulate matters are created in the air through complex interaction of chemical matters such as SOx and NOx exhausted from power plants, factories, and motor vehicles.

Particulate matters are classified into two groups as follows.

PM10 : inhalable particle with a diameter below 10 micrometer

PM2.5 : inhalable particle with a diameter below 2.5 micrometer

Impacts on Human Health

PM10 penetrates deep into lungs and even bloodstream. Further, PM2.5 would gives largest risk to health.

Impacts on Environment

Particulate matter causes mists in the air.

2. Air Pollution Policy of Tanzanian Government

The Tanzanian Government is implementing the Health and Pollution Action Plan (HPAP) process to control environmental pollution. HPAP includes 5 big projects with regard to management of air quality in urban area, improvement of water quality, reducing leak of contamination matters at small mines, reduction of domestic air pollution by cooking at home, management of agricultural chemicals to enhance both harvests and health. It also lists 5 factors threating health including pollution of domestic air, outer air, water, soil by contamination with heavy metals and dangerous chemical matters, and exposure to dangerous materials at work[45].

Motor vehicles are responsible for air quality in the urban area. Presently, energy intensive industries are not many in Tanzania, and hence emissions of air pollution matters from such factories are limited. Emissions from motor vehicles comprise main source of air pollution in the urban area.

Figure 6.4-5 shows an example of air pollution in India. Taj Mahal is a masterpiece of Islamic arts and registered as a world heritage. The photo in left was taken in November in a dry season, when visibility was limited due to smog despite it was fine day. The photo on the right was taken at the end of the dry season; rain in the morning had washed down the smog. View is clear, but the rain may have been acid rain and eroded marbles at the structure.

15 November 2008

(Dry Season)

13 March 2011

(End of Dry Season)

Source: JICA Study Team

Figure 6.4-5 An Example of Air Pollution in India

As Taj Mahal is located inland of India, and there is least rain and wind during the dry season, exhaust gas from factories and motor vehicles continues floating in the air for long time and cause smog.

Presently, Tanzania is not suffering from serious air pollution like India, however serious air

[45] Japan Embassy in Tanzania, https://www.facebooCok.com/tanzania.business.news/posts/2357902864424832/

pollution would be triggered in Dodoma under semi-desert climate when rapid urbanization progresses and incur abrupt increase of motor vehicles. Cars in Tanzania are mostly old, some are not equipped with air pollution control apparatus and would cause air pollution especially particulate matters.

In view of the above, as an approach to control air pollution anticipated in future, it is efficient to introduce NGVs that would not create PM. In particular, it is preferable to give priority on natural gas switching of large freight trucks from diesel, old ones of which emit much more particulates compared with passenger cars.

6.4.4 Issues Relating to Global Warming

CO_2 emissions in Tanzania by fossil fuel burning was 0.03% of the global total amount in 2017, and the country is not keenly noticed in discussions on global warming issues[46]. In September 2015, in prior to the COP21 Meeting, Tanzania announced its INDCs (Intended Nationally Determined Contributions) that it will reduce GHG emissions by 10-20% from the BAU scenario in 2030.

CO_2 emission by burning natural gas is about 20% smaller compared with that for petrol and diesel oil, and therefore GHG reduction by introducing NGVs is significant.

However, there are some issues on introducing NGVs in Tanzania in relation to global warming. For introduction of NGVs in Tanzania, the first option may be conversion of used gasoline vehicles to natural gas use. By such conversion, it is anticipated that natural gas would not be burnt completely in the engine and some unburnt natural gas would be released into the air (Methane Slip). Since natural gas has considerably greater effect of global warming compared with CO_2, tenth of times, we should carefully examine introduction of natural gas altering diesel in view of global warming. In this regard, introducing NGVs, it may be preferable to give priority to LNG trucks that would cause least Methane Slip.

On the other hand, although emission of unburnt natural gas is a problem in view of global warming, natural gas of Tanzania would cause less problems in relation to air pollution. That is, while unburnt hydrocarbons such as gasoline would become a source of photochemical oxidants and its release into the air should be controlled, Tanzanian natural gas comprises mostly methane that is low in photochemical activity and would cause less problems of air pollution by photochemical oxidant.

6.4.5 Summary

Reviewing possibility of NGV introduction in Tanzania from four viewpoints, we consider it as a preferable option to introduce natural gas as motor fuel in this country. An issue is that natural gas supply infrastructure is presently quite limited in Tanzania. In countries where NGVs are

[46] CO_2 Emission From Fuel Combustion 2019, IEA

introduced to a certain extent, natural gas supply infrastructure, in particular city gas, is already developed.

Introducing NGVs into Tanzania, we face the dilemma which should be the first to construct natural gas supply infrastructure or to develop natural gas demand. As such, it will be necessary to consider following four requisite conditions in approaching NGV introduction in Tanzania.

a. To implement construction of natural gas supply infrastructure and demand creation simultaneously.

b. To construct certain size of natural gas infrastructure within a short period of time.

c. To create certain size of natural gas demand within a short period of time that can justify economics of the system.

d. For simultaneous creation of natural gas supply infrastructure and natural gas demand within a short period of time, collaboration of the supply and demand sides is necessary. To achieve this quickly, it is preferable to have a small number of participants at the beginning.

It may take time to construct a CNG stand network utilising city gas delivery networks. As passenger vehicles are small in CNG consumption per unit, and there will be a considerably large number of drivers, penetration of CNG vehicles will take time. Thus, passenger cars may be given less priority for introduction of CNG.

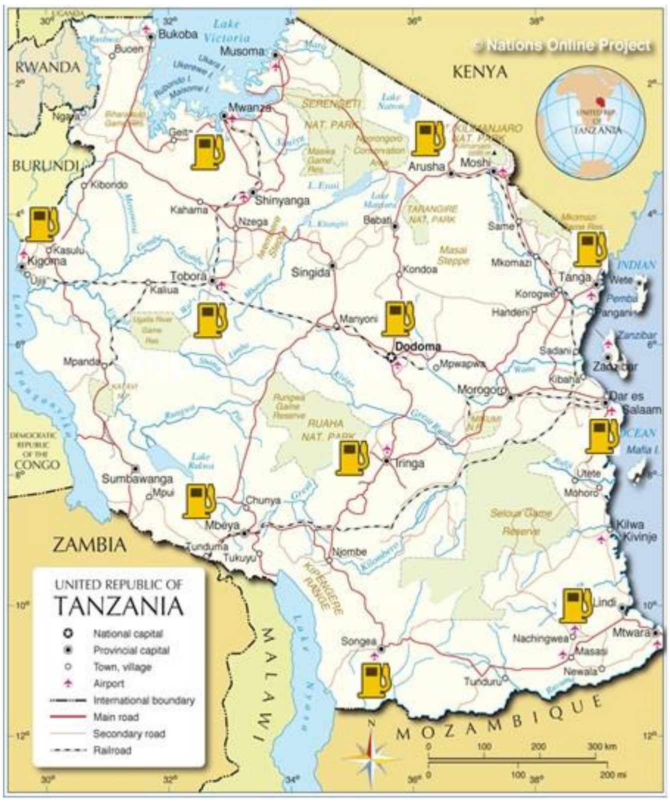
On the other hand, introduction of LNG for large trucks is thought to suffice the above four conditions. Since LNG trucks consume a greater amount of natural gas per vehicle, much less time would be necessary to put an LNG station network on track compared with construction of city gas network. In addition, an LNG station network can be developed once agreed among three parties, cargo owners, transport companies and customer, and be materialised within a relatively short time if conditions are met.

From the above discussion, we consider that, for NGV introduction in Tanzania, priority should be given for construction of LNG corridors and introduction of LNG trucks. And adopting L-CNG stations, CNG vehicles will also be served and other possibilities can be pursued such as construction of mini-gas grid around the station and promotion of local electrification using the station as the base for distributed gas power generation.

(1) LNG Corridor

To introduce LNG trucks for transportation, it is necessary to construct LNG corridors, or a network of LNG filling stations within a country. LNG kept by an LNG truck incurs BOG as time goes by, it is preferable for vehicles used for regular services such as fixed route services. And it is preferable that a fuel tank is almost empty at the time of filling. In view of these, fixed route trucks and buses on regular service are the most preferable option for LNG use. Tanzania being a continental country and development of freight transport system in the interior areas is one of the important pillars of the economic development policies, creation of LNG corridors will significantly contribute to this target.

Assuming that an average driving distance of an LNG truck by one fuel filling at 500 km, a minimum number of LNG filling stations need to be developed as shown in the Figure 6.4-6. In actual application, it will be desirable to put service stations with an interval at a half of the driving distance.



Source: JICA Study Team

Figure 6.4-6 LNG Corridor in Tanzania

(2) Issues for Introduction of LNG Truck

Following issues are anticipated and should be examined for promoting introduction of LNG trucks.

a. Construction Cost of LNG Station Network

Construction cost of LNG (L-CNG) station will be higher compared with regular service stations for petrol and diesel.

b. Import Cost of LNG Truck

Presently, many used trucks are imported in Tanzania. In case of LNG trucks, new vehicles may need to be imported causing higher cost.

c. Training Cost

It is necessary for LNG truck drivers to go through education and training on LNG handling and safety, and obtain specific license. Operators at LNG (L-CNG) stations may need similar education and training. These would cause higher personnel cost for operation of an LNG station.

As LNG kept in tanks of an LNG truck will start boiling off in about five days, it is desirable that the fuel tank is empty at time of refilling after the run and unloading. To create a transportation system by LNG trucks, it is necessary for cargo owners, receivers and transport companies to collaborate closely.

d. Legal System for Safety

LNG is liquid at extremely low temperature of -162℃: if leaked, it would vaporise and bring about high GHG effect or, if ignited, burn explosively. Therefore, it is necessary to set out proper safety standard to handle LNG.

Chapter 7 Gas Demand for DNGPP Model Project

Energy demand analysis in Chapter 5 and 6 has revealed that sufficient energy demand is not readily available in regions of Tanzania outside Dar es Salaam that would justify any standalone city gas project. However, recent development of *virtual pipeline* technology has made it possible to collect small-medium gas demands scattered in a wide area into one cluster and create a viable gas supply system. Virtual pipeline is a system to transport natural gas in small lots in the form of liquefied natural gas (LNG) or compressed natural gas (CNG) as explained in Chapter 7. These may suggest feasibility of establishing a new natural gas supply system in Tanzania assembling various types of potential demands.

Under the circumstance, we examine if a virtual pipeline system is viable for natural gas distribution in Tanzania and which method of gas transport is preferable. To this end, we develop prospective gas demand scenarios and set out model cases for evaluation in this chapter.

Given that extensive development is scheduled for Dodoma as the national capital, development of city gas system in Dodoma will be one of the pillars of this project. Then, large industry energy users located elsewhere in the north eastern regions of Tanzania are considered as the second pillar. They would not be connected to the Dodoma city gas systems but receive gas by bulk transport by way of virtual pipeline system. As suggested in Chapter 5 by demand reading from Google Map, factories are mostly placed in industrial areas. In such cities, District Gas System may be considered for integrated supply of natural gas for a cluster of factories, and, in turn, it will be co-used for a city gas network. Thirdly, natural gas supply for motor vehicles (NGVs: natural gas vehicles) is considered. Gas demand for NGVs may start with a small quantity but may grow significantly as vehicle ownership expands in the future. If a virtual pipeline project is viable based on these demands, gas distribution will be further extended to scattered users such as factories in other regions and rural electrification programs.

Aggregating the above investigation, gas demand scenarios for a model natural gas supply system are projected as below.

7.1 City Gas Demand in Dodoma

For development of city gas system, we assume three projects in Dodoma for the first phase of gasification; at the New Government City, the central area of the existing city designated as Central Business District and the Iyumbu Satellite Centre development project as shown in Figure 7.1-1. They are presumed to have high potential for introducing city gas in view of the ongoing plans to develop the capital.

City Gas Plan-A:

At Ihumwa approximately 17 km east of Dodoma City, construction of the New Government City (NGC) has started. A city gas system may be built from its very early construction stage.

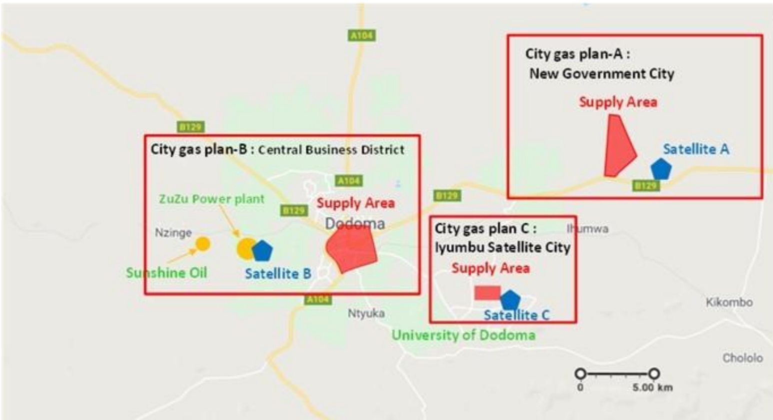
City gas will be supplied to office buildings, public facilities, commercial facilities, embassies, and residences for government officials and diplomats in the area. Residents are high income class with favours for modern life. These will collectively provide gas demand for construction of a city gas supply system in the new capital. In addition, introducing CHP into a large government buildings and public facilities, it will be possible to line up a large gas demand to expand the project platform.

City Gas Plan-B:

The central part of Dodoma City is designated as the Central Business District (CBD) under the Dodoma National Capital City Master Plan[47]. This area is selected for the first phase of gasification in the urban area. The object area is the core part of the present city densely developed with government offices, business buildings, commercial facilities, hospitals, houses, etc., while the residential density is not so high. Along the Kikuyu Avenue in the south of the Dodoma Station, there are also government agencies such as the Prime Minister's office and the Central Bank. As new SGR station is being built the south, more office buildings and commercial facilities will be constructed in this area. After successful development of the phase-1 of the city gas project, the system will be expanded to surrounding areas.

City Gas Plan-C:

A new township is being developed in Iyumbu near the University of Dodoma. City gas supply system may be developed at this Iyumbu Satellite Centre as Plan-C. Although it is a small project compared with Plan-A and Plan-B, the residential density is high and residents are of higher income class. Construction of commercial facilities is planned in the later stage of the project.



Source: JICA Study Team

Figure 7.1-1 City Gas Supply Plan in Dodoma

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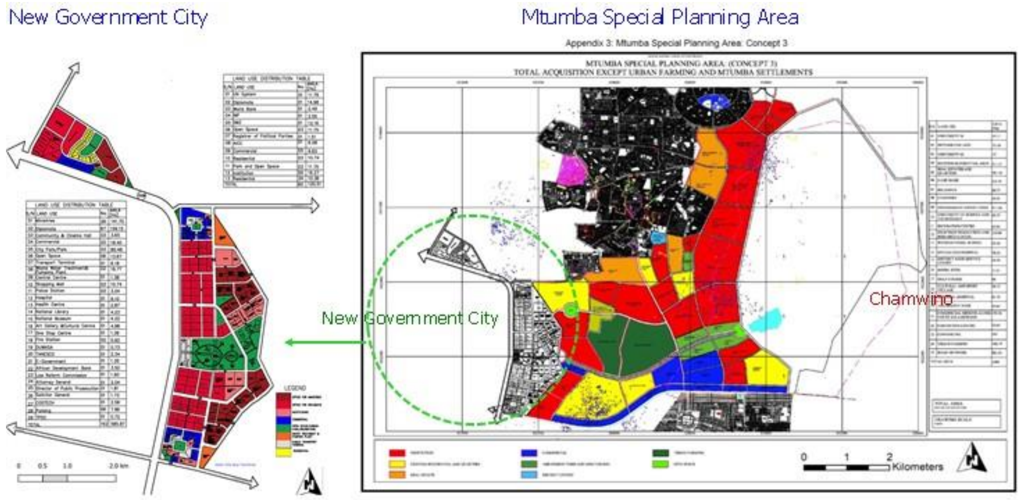
47 Ministry of Lands, Housing and Human Settlements Development, "Dodoma National Capital city Master Plan (2019-2039)," April 2019

7.1.1 New Government City (Plan-A)

The New Government City (NGC) is being built at Ihumwa 17 km east of the Dodoma city centre. According to the "Dodoma Capital City Master Plan", Mtumba Special Planning Area will be developed on the east of the NGC.



Source: Dodoma National Capital City Master Plan (2019-2039)

Figure 7.1-2 New Government City at Dodoma

Source: Dodoma National Capital City Master Plan (2019-2039)

Figure 7.1-3 Aerial Drawing of the NGC Plan

The Master Plan illustrates construction of buildings and facilities in the new capital city as shown in Figure 7.1-3. Based on this drawing, the Study Team has tried to estimate the fuel demand in the NGC. Fuel demand will arise at government offices, business buildings, commercial facilities, public facilities, schools and residences. Energy consumption is significantly different among different type facilities. Table 7.1-1 shows the IEEJ's research outcome on energy consumption in Japan at various business/commercial facilities. Generally, most of the energy consumed at these facilities is electricity from the grid and is used for lighting, air-conditioning, ITs and utility services. Natural gas is occasionally used for power generation, air conditioning and heating, but cooking and hot water supply are the main applications. Thus, except for restaurants and hotels, fuel (mainly city gas) ratio is low among their energy consumption. Then, we estimate that energy intensities in Tanzania will be slightly lower than that in Japan (90%) as requirement for air/water heating in wintertime is lower.

Table 7.1-1 Energy Consumption for Major Facilities in Japan

	Energy Intensity		Fuel Ratio	Annual Consumption	
	Japan	Tanzania		Power	Fuel
	MJ/y/m^2	90%		kWh	kgoe
Large Building	1,575	1,400	5%	369	1.7
Office Building	1,920	1,700	10%	425	4.1
Department/Super market	3,425	3,100	10%	775	7.4
Smaller shops at building	3,148	2,800	5%	739	3.3
Restaurants	5,012	4,500	33%	833	35.8
Hospitals	3,050	2,700	17%	625	10.8
Clinics	1,294	1,200	10%	300	2.9
Universities/Colleges	1,157	1,000	10%	250	2.4
Hotels	3,133	2,800	33%	519	22.3

Source: IEEJ

The construction plan shown in Figure 7.1-1 is re-compiled considering allocated space for each land use and plausible building size. Applying the energy consumption intensities shown in Table 7.1-1, the fuel demand at the New Government City is estimated as shown in Table 7.1-2. At these facilities, most of the energy consumption is electricity; fuel consumption is estimated to be relatively small, at about 5,400 tons LNG equivalent per year once all of them are built. This may compare to gas consumption at a small-medium size factory and looks like too small to implement a standalone city gas project. As shown in the table, electricity demand will dominate at the office buildings and commercial facilities amounting to 93% of the total energy consumption, which is estimated to be 77,000 tonnes per year in LNG equivalent.

In order to speed up the investment recovery of the city gas system, it is desirable to introduce large scale gas users. To this end, we propose introduction of CHP (Combined Heat and Power) and GHP (Gas Heat Pump) systems to absorb electricity demand with gas power generation and achieve a high energy efficiency. Individual CHP systems may be introduced at office buildings, embassies, large department stores and hotels or District Energy System (DES) may be considered as an integrated system to cover them. If CHP or DES takes up a 50% of the electricity demand at these facilities, gas demand will exceed 70,000 tons LNG equivalent.[48] Utilizing the exhaust heat from the power generation system, a CHP system usually brings 70-80% energy efficiency while the best efficiency of the most modern CCGT in operation in Japan is 62%. Gas heat pump (GHP) may also be considered for cooling demand, which will further expand the fuel demand.

48 991,526 MWh x 50% / 50% efficiency x 860 kcal/kw/11,936 kcal/kg=71,440 tons LNG

In the Master Plan, only 37 residences are scheduled in the residential area, which is greatly reduced from the early plan. These residences may be considered for diplomatic and other international officers. According to "Dodoma Capital City Master Plan" announced in 2019, it is scheduled that the Mtumba Special Development Areas will be developed annexed to the NGC. General officers and workers may reside in these areas around the NGC. Residential gas demand will mainly arise in these areas. Though such demand may be small in the early stage and need time to build up, these potential demands should also be considered in designing the city gas plan.

Table 7.1-2 Building Plans and Fuel Consumption at NGC

Annex

LAND USE DISTRIBUTION TABLE				Building Space			Energy Use		Energy Demand			
S/N	LAND USE	No.	Area	Stories	Space	Total	Intensity	Fuel Ratio	Electricity		Fuel	LNG
			ha		m^2	m^2	$MJ/y/m^2$		MWh	MW	toe	t
1	UN System	1	11.79	2	35,000	35,000	1,500	5%	13,854	1.6	62.7	52.7
2	Diplomats	1	14.98	2	30,000	30,000	1,500	5%	11,875	1.4	53.8	45.2
3	World Bank	1	2.49	2	10,000	10,000	1,500	5%	3,958	0.5	17.9	15.1
4	IMF	1	2.55	2	10,000	10,000	1,500	5%	3,958	0.5	17.9	15.1
5	SMZ	1	12.16	2	12,000	12,000	1,500	5%	4,750	0.5	21.5	18.1
6	Open Space	3	11.75	0	0	0				0.0	0.0	0.0
7	Registrar of Politicial Parties	1	1.51	2	6,000	6,000	1,500	5%	2,375	0.3	10.8	9.0
8	AICC	1	6.08	2	24,000	24,000	500	5%	3,167	0.4	14.3	12.0
9	Commercial	5	9.62	2	8,000	40,000	3,000	10%	30,000	3.4	286.7	240.9
10	Residential	3	10.74	2	7,000	21,000	1,000	10%	5,250	0.6	50.2	42.2
11	Park and Open Space	3	11.75	0	0	0				0.0	0.0	0.0
12	Institution	5	16.27	2	10,000	50,000	1,500	5%	19,792	2.3	89.6	75.3
13	Residential	34	10.36	2	1,200	40,800	1,000	10%	10,200	1.2	97.5	81.9
	TOTAL	60	120.51						109,179	12.5	723	607

Central Area

LAND USE DISTRIBUTION TABLE				Building Space			Energy Use					
S/N	LAND USE	No.	Area	Stories	Round	Total	Intensity	Fuel Ratio	Electricity		Fuel	LNG
			ha		m^2	m^2	$MJ/y/m^2$		MWh	MW	toe	t
1	Ministries	26	141.70	4	33,000	858,000	1,500	5%	339,625	38.8	1,537.3	1,291.8
2	Diplomats	67	159.15	2	7,000	469,000	1,500	5%	185,646	21.2	840.3	706.1
3	Community & Cinema Hall	3	3.65	2	5,000	15,000	3,000	5%	11,875	1.4	53.8	45.2
4	Commercial	22	18.40	4	8,000	176,000	3,000	10%	132,000	15.1	1,261.3	1,059.9
5	City Park / Park	3	85.48	0	0	0	0	0%	0	0.0	0.0	0.0
6	Open Space	6	13.67	0	0	0	0	0%	0	0.0	0.0	0.0
7	Transport Terminal	1	6.18	4	25,000	25,000	1,500	5%	9,896	1.1	44.8	37.6
8	Waste Water Treatment & Pumping Plant	2	16.77	2	8,000	16,000	5,000	0%	22,222	2.5	0.0	0.0
9	Control Centre	1	1.38	4	11,000	11,000	1,500	5%	4,354	0.5	19.7	16.6
10	Shopping Mall	3	10.74	4	36,000	108,000	3,000	10%	81,000	9.2	774.0	650.4
11	Police Station	3	3.24	4	4,000	12,000	1,500	5%	4,750	0.5	21.5	18.1
12	Hospital	1	9.10	4	55,000	55,000	3,000	20%	36,667	4.2	788.3	662.5
13	Health Centre	1	2.87	4	17,000	17,000	3,000	10%	12,750	1.5	121.8	102.4
14	National Library	1	4.23	2	13,000	13,000	1,000	5%	3,431	0.4	15.5	13.0
15	National Museum	1	4.22	2	13,000	13,000	1,000	5%	3,431	0.4	15.5	13.0
16	Art Gallery & Cultural Centre	1	4.98	2	15,000	15,000	1,000	5%	3,958	0.5	17.9	15.1
17	One Stop Centre	1	1.39	2	6,000	6,000	1,500	5%	2,375	0.3	10.8	9.0
18	Fire Station	2	0.92	2	2,000	4,000	1,500	5%	1,583	0.2	7.2	6.0
19	DUWASA	1	0.73	2	3,000	3,000	1,500	5%	1,188	0.1	5.4	4.5
20	TANESCO	1	2.34	2	9,000	9,000	1,500	5%	3,563	0.4	16.1	13.6
21	E-Government	1	1.35	2	5,000	5,000	2,000	5%	2,639	0.3	11.9	10.0
22	African Development Bank	1	3.50	2	14,000	14,000	1,500	5%	5,542	0.6	25.1	21.1
23	Law Reform Cmmission	1	1.90	2	6,000	6,000	1,500	5%	2,375	0.3	10.8	9.0
24	Attorney General	1	2.04	2	6,000	6,000	1,500	5%	2,375	0.3	10.8	9.0
25	Director of Public Prosecution	1	1.81	2	5,000	5,000	1,500	5%	1,979	0.2	9.0	7.5
26	Solicitor General	1	1.73	2	5,000	5,000	1,500	5%	1,979	0.2	9.0	7.5
27	COSTECH	1	2.58	2	10,000	10,000	1,500	5%	3,958	0.5	17.9	15.1
28	Parking	6	7.86	0	0	0	0	0%	0	0.0	0.0	0.0
29	TPDC	1	0.72	2	3,000	3,000	1,500	5%	1,188	0.1	5.4	4.5
	TOTAL	162	585.87						882,347	101	5,651	4,749
											toe	t-LNG
								Grand Total	991,526	113	6,374	5,356
							15	hours/day	181	MW--> PS Capacity: 360 MW		

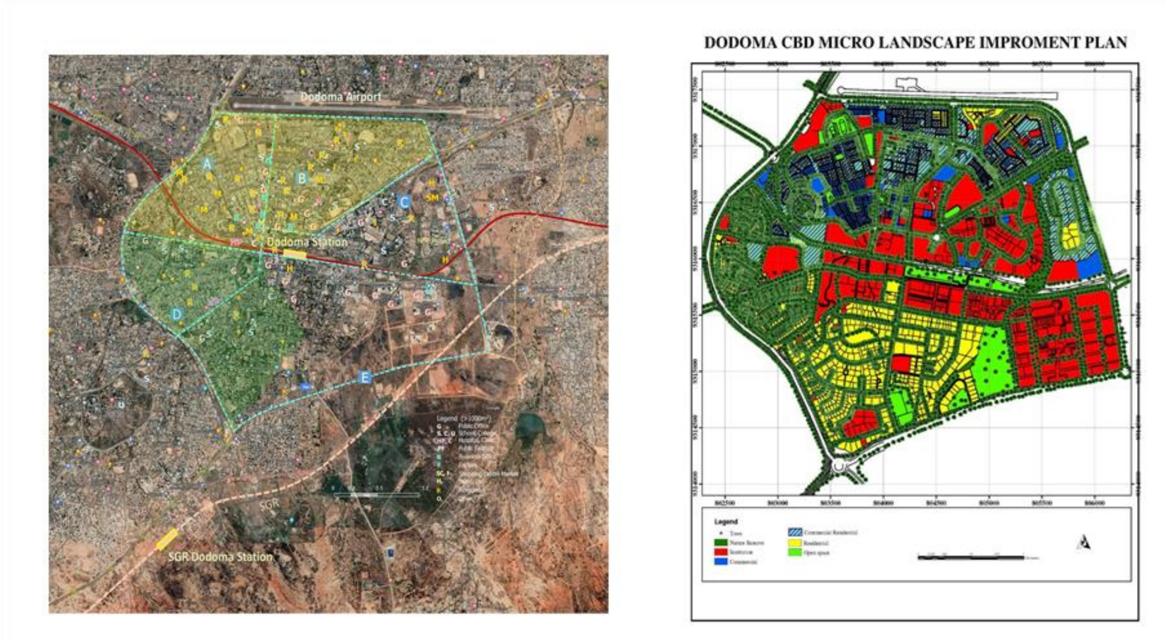
Total Energy Consumption	t-LNG	
Electricity	71,657	93.0%
Gas	5,356	7.0%
Total	77,013	100.0%

To generate electricity at 50% efficiency, 140,000 tons of LNG is necessary.

Source: JICA Study Team

7.1.2 Dodoma City Centre (Plan-B)

The city centre of Dodoma as shown in Figure 7.1-4 is nominated as the Central Business District (CBD) under the Dodoma City Master Plan as the core business/commercial area and be



Source: Study Team compiled on Google Map, Dodoma National Capital City Master Plan

Figure 7.1-4 Central Part of Dodoma as Central Business District (CBD)

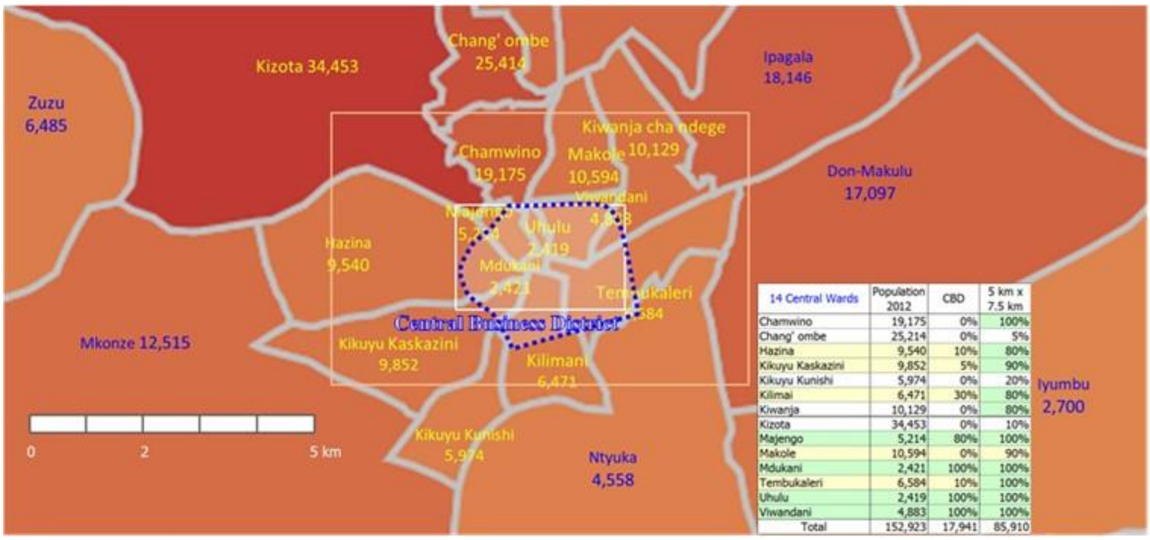
The northern part of CBD is the old town well developed with administration and business offices, markets and shops, while the southern part is residential area. The eastern part is presently being developed with construction of government facilities, hotels, shopping centres and multi-story apartments. SGR Dodoma station is being built about 1 km southwest of the CBD; it will become another core for the development.

Table 7.1-3 Buildings and Facilities in the Present CBD

	Low Rise (up to 2 stories)	Multiple Stories	Notes
House and Building	2628	27	NHC: 4 rows x 5 stories= 20 apartments/building
Restaurants	84		Many are co-operated at hotels and inns
Shops	97		According to Google labeling
Office	36	27	High-rises are mainly government offices
Public Facility	3		Parliament, railway station, etc.
Hotel	1	2	New Dodoma, Nashera, Moreha
Inn	49		According to Google labeling
Hospital	5		Dodoma Regional Referral Hospital
School	11		
Market & mall	8		Shoppers Plaza, Sabasaba, Soko Kuu, etc.
Religeous Facility	22		

Source: Compiled by Study team from Google Map

Counting the Google labelling, number of houses, buildings and other institutions are summarized in Table 7.1-3. If we assume 5 family members per house and double story ratio of 30% for houses, the present population of this area is estimated to be around 20,000. According to the 2012 Census, population in the central part of Dodoma is distributed as shown in Figure 7.1-5. Based on it, population of the CBD is estimated to be about 18,000 in 2012. This area held only 4.4% of the total population of 410,956 in Dodoma city.



14 Central Wards	Population 2012	CBD	5 km x 7.5 km
Chamwino	19,175	0%	100%
Chang' ombe	25,214	0%	5%
Hazina	9,540	10%	80%
Kikuyu Kaskazini	9,852	5%	90%
Kikuyu Kunishi	5,974	0%	20%
Kilimai	6,471	30%	80%
Kiwanja	10,129	0%	80%
Kizota	34,453	0%	10%
Majengo	5,214	80%	100%
Makole	10,594	0%	90%
Mdukani	2,421	100%	100%
Tembukaleri	6,584	10%	100%
Uhulu	2,419	100%	100%
Viwandani	4,883	100%	100%
Total	152,923	17,941	85,910

Source: NBS

Figure 7.1-5 Population Distribution at the Centre of Dodoma as of 2012

For estimation of the future demand, we assume that the population of Dodoma City will increase at a very high growth rate to 727 thousand people in 2025 (at 6.0% of annual growth rate from 2017 to 2025) and 915 thousand people in 2030 (at 4.6% of annual growth rate from 2025 to 2030). Reflecting the movement of government officers, population growth was very fast during the last five years. However, some of the people may move to the newly developed areas such as the NGC and Iyumbu Satellite Centre. Therefore, if we assume that the future population growth rate of the CBD would be about a half of the total, population of the CBD will be 28,000 in 2025 and 31,000 in 2030.

If all households in the city gas project area use city gas and one person consumes 100 kgoe of gas a year, the gas demand will be 2,800 toe (2,350 tons LNG equivalent) in 2025 and 3,100 toe (2,600 tons LNG equivalent). However, such demand will increase step by step. Therefore, it is assumed that the residential demand for city gas will start with a demand at 1,500 tons LNG equivalent in 2025 and increases to 2,500 tons LNG equivalent in 2030. Also, based on the presumable number of buildings and facilities in the project area, the fuel demand of the commercial sector is estimated as shown in Table 7.1-4. Fuel consumption at these sectors will be about 6,000 tons LNG equivalent per year in 2030. Thus, we assume that the business/commercial sector demand for city gas may start at 2,000 tons in 2025 and grow to 4,000 tons in 2030.

Table 7.1-4 Fuel Demand of Commercial Sector in Project Area

	Specification of Individual Unit								Aggregate Energy Consumption				
	Space					Electricity		Fuel	Unit	Electricity	Oil equiv	Fuel	LNG equiv
	m	m	m^2	Floor	m^2	MWh/year	kW	toe		MWh/year	toe/year	toe/year	t/year
Office Building	30	40	1200	5	6,000	2,550	291	24.4	100	255,000	21,930	2,437	2,041
Department/Super market	50	100	5000	2	10,000	7,750	885	74.1	12	93,000	7,998	889	745
Smaller shops at building	10	20	200	1	200	148	17	0.7	150	22,167	1,906	100	84
Restaurants	10	20	200	1	200	167	19	7.2	150	25,000	2,150	1,075	901
Hospitals	40	50	2000	5	10,000	6,250	713	107.5	5	31,250	2,688	538	450
Clinics	10	20	200	1	200	60	7	0.6	20	1,200	103	11	10
School,etc	40	50	2000	2	4,000	1,000	114	9.6	2	2,000	172	19	16
Hotels (+ Inns x 1/4)	30	50	1500	3	4,500	2,333	266	100.3	20	46,667	4,013	2,007	1,681
Official Residence, etc.	30	50	1500	3	4,500	1,913	218	18.3	5	9,563	822	91	77
Total									464	485,846	41,783	7,167	**6,004**
										CHP	28,826	35,993	30,155

Source: JICA Study Team

The potential of fuel consumption for CHP is also estimated same as section 7.1.1. If CHP systems are introduced at office buildings and hotels having large energy demand and a 50% of the electricity demand at these facilities (yellow column) are covered by CHP system, gas demand will amount to about 29,000 toe per year (or 24,150[49] tons LNG equivalent).

7.1.3 Iyumbu Satellite Centre (Plan-C)

It is planned that 413 houses and mass housings for 500 households will be built in the Iyumbu Satellite Centre. Assuming six family members per household, the population of the Iyumbu Satellite Centre will be 5,478. Further assuming that one person consumes 100 kgoe of fuel, the aggregate annual fuel demand will be 550 toe (460 tons LNG equivalent). Also, based on the assumed number of commercial and other facilities, the fuel consumption in the commercial sector is estimated as shown in Table 7.1-5. In these facilities, most of the energy consumption is electricity, while fuel consumption is estimated to be relatively small, about 420 tons LNG equivalent.

Table 7.1-5 Fuel Consumption of Commercial Sector in Iyumbu Satellite Centre

	Specification of Individual Unit								Aggregate Energy Consumption				
	Space					Electricity		Fuel	Unit	Electricity	Oil equiv	Fuel	LNG equiv
	m	m	m^2	Floor	m^2	MWh/year	kW	toe		MWh/year	toe/year	toe/year	t/year
Office Building	30	40	1200	5	6,000	2,550	291	24.4	3	7,650	658	73	61
Department/Super market	50	100	5000	2	10,000	7,750	885	74.1	1	7,750	667	74	62
Smaller shops at building	10	20	200	1	200	148	17	0.7	23	3,399	292	15	13
Restaurants	10	20	200	1	200	167	19	7.2	23	3,833	330	165	138
Hospitals	40	50	2000	5	10,000	6,250	713	107.5	0	0	0	0	0
Clinics	10	20	200	1	200	60	7	0.6	0	0	0	0	0
School,etc	40	50	2000	2	4,000	1,000	114	9.6	1	1,000	86	10	8
Hotels	30	50	1500	5	7,500	3,889	444	167.2	1	3,889	334	167	140
Embassies, etc.	30	50	1500	3	4,500	1,913	218	18.3	0	0	0	0	0
Total									52	27,521	2,367	504	**422**
										CHP	1,843	2,347	1,967

Source: JICA Study Team

49 (Office building power demand 21,930 toe + Hotel 4,013toe) × 50% / generation efficiency 45% × (10,000 kcal / kgoe / 11,936 kcal / LNG-kg) =24,150 ton LNG equivalent

Assuming also that CHP system will be introduced for office buildings, large department stores and hotels with large energy demand, and a 50% of the electricity demand of these facilities will be covered by CHP system, gas demand will amount to about 1,840 toe per year (1,540[50] tons LNG equivalent).

7.2 Bulk Delivery for Large Factories

From the outcome of the Rural Energy Demand Survey (REDS), 19 factories with monthly fuel consumption over 20 toe are extracted as shown in Table 7.2-1. Users who consume LNG more than one container quantity per month are selected; LNG container size may be 12-20 tons or 15-25 tons oil equivalent. Among these, factories not connected to gas pipelines may receive LNG by tank trucks or containers as bulk delivery. Fuel consumptions at hotels, restaurants and public facilities are yet small in Tanzania, and hence not considered in this study. However, when the virtual gas pipeline system is well established, these sectors may also become core demand sectors.

Table 7.2-1 List of Factories with monthly fuel consumption over 20 toe

Large factories with potential monthly fuel demand more than 20 toe		Products	2018		2025	to grow at	6%	2030	to grow at	6%
			Monthly	Annual	Annual	100%	70%	Annual	100%	70%
			toe	toe	toe	toe	toe	toe	toe	toe
Arusha	Tanzania Brewary Ltd.	Beer	34	404	608	600	400	813	800	600
	A to Z Textile	Textile	35	417	627	600	400	839	800	600
	Sub-total		68	821	1,235	1,200	900	1,652	1,700	1,200
Dodoma	Sunshine Industrial Limited	Cooking oil	372	4,459	6,705	6,700	4,700	8,973	9,000	6,300
	Sub-total		372	4,459	6,705	6,700	4,700	8,973	9,000	6,300
Mbeya	Tanzania Brewary Ltd	Beer	44	526	791	800	600	1,058	1,100	700
	Sub-total		44	526	791	800	600	1,058	1,100	700
Morogoro	21st Century Textile	Textile	543	6,517	9,799	9,800	6,900	13,113	13,100	9,200
	Alliance One Tobacco	Tobacco	115	1,381	2,077	2,100	1,500	2,780	2,800	1,900
	Tanzania Tobacco	Tobacco	188	2,258	3,396	3,400	2,400	4,544	4,500	3,200
	Sub-total		846	10,157	15,272	15,300	10,700	20,437	20,400	14,300
Moshi	Bonite Bottlers	Soft drinks	47	568	854	900	600	908	900	600
	Sub-total		47	568	854	900	600	908	900	600
Mwanza	Mwatex	Textile	170	2,036	3,061	3,100	2,100	4,097	4,100	2,900
	Nyakato Steel Mills	Steel	89	1,064	1,599	1,600	1,100	2,140	2,100	1,500
	Mwanza Wines	Wine	88	1,057	1,589	1,600	1,100	2,126	2,100	1,500
	Sayona Drinks	Soft drinks	110	1,316	1,978	2,000	1,400	2,647	2,600	1,900
	Serengetti Brewaries	Beer	954	11,443	17,206	17,200	12,000	23,026	23,000	16,100
	Nayanza bottling	soft drinks	52	627	942	900	700	1,261	1,300	900
	Sub-total		1,462	17,542	26,376	26,400	18,500	35,297	35,300	24,700
Tanga	Gulam Patter Coconut Oil	Cooking oil	63	761	1,144	1,100	800	1,531	1,500	1,100
	Kilimanjaro Cement	Cement	505	6,065	9,180	9,200	6,400	12,284	12,300	8,600
	Tanga Cement	Cement	5,443	65,322	98,870	98,900	69,200	132,311	132,300	92,600
	Tanga Fresh	Milk products	27	322	487	500	300	652	700	500
	Neelkanth Lime Ltd	Lime	479	5,754	8,709	8,700	6,100	11,654	11,700	8,200
	Sub-total		6,519	78,223	118,389	118,400	82,800	158,432	158,400	110,900
Total										
	7 cities		9,358	112,295	169,622	169,700	**118,800**	226,758	226,800	**158,700**
	5 cities		7,852	94,228	142,455	142,500	**99,700**	190,403	190,400	**133,300**
	5 cites excl. Cement and Lime		1,424	17,088	25,697	25,700	**18,000**	34,154	34,100	**23,900**

Groth rate @ 10 %

Large factories with potential monthly fuel demand more than 20 toe		Products	2018		2025	to grow at	10%	2030	to grow at	10%
			Monthly	Annual	Annual	100%	70%	Annual	100%	70%
Total										
	7 cities		9,358	112,295	185,126	185,100	**129,600**	297,576	297,700	**208,200**
	5 cities		7,852	94,228	149,917	149,900	**105,000**	240,873	240,900	**168,500**
	5 cites excl. Cement and Lime		1,424	17,088	33,159	33,100	**23,300**	52,832	52,900	**36,900**

50 (Office building power demand 658 toe + department store 667 toe + hotel 334toe) × 50% / generation efficiency 45% × (10,000 kcal / kgoe / 11,936 kcal / LNG-kg) = 1,544 ton LNG equivalent

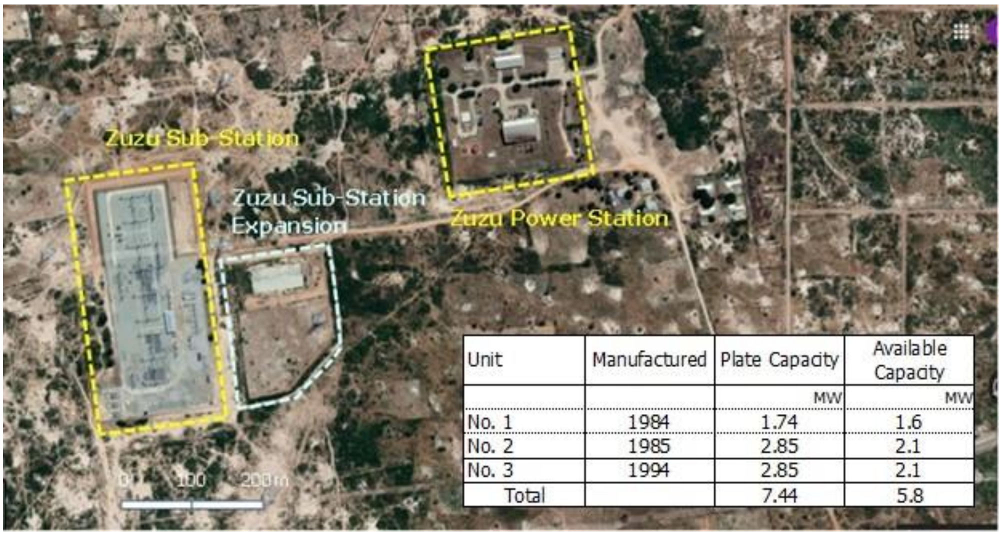
The plausible fuel consumption by potential users is compiled in Table 7.2-1, which is estimated based on the REDS outcome and applying the average growth rate of the industrial sector fuel consumption for the whole country, or annual 6%. As shown in the table, the total fuel consumption of the factories in seven cities will be 169.7 ktoe in 2025 and 226.8 ktoe in 2030.

However, on the customer list for the first program of the virtual pipeline development, we may have to exclude those factories in Mbeya and Mwanza with a longer transport distance and cement and limestone factories in Tanga using low cost fuel such as coal. They may become gas consumers in future, but it may take time to persuade them because of high hurdles. Then, the fuel demand potentially switching to gas will be reduced to 25.7 ktoe in 2025 and 34.1 ktoe in 2030. If we assume a gas switching ratio at 70%, the probable gas demand will be 18.0 ktoe (15,164 tons LNG equivalent) in 2025 and 23.9 ktoe (20,023 tons LNG equivalent) in 2030. In case the average annual growth rate picks up to 10%, the expected gas demand will be 23.3 ktoe in 2025 and 36.9 ktoe in 2030.

The above scenario is developed on the limited amount of information obtained by the REDS 2018. As discussed in Section 5.6, more affirmative information is necessary to set a credible sales plan that will justify a tangible project. To this end, the Study Team proposed conduct of market research on individual large energy users.

7.3 Zuzu Power Station

The Zuzu power station is located about 5km west of Dodoma city. It is powered by diesel engines with the plate capacity of 7.44MW and the available capacity 5.8MW, and is operated for peak-shaving with an annual average load of 10-15%. As the present plant is already obsolete, we consider an optional case that the Zuzu power station will be retrofitted to use natural gas. This will provide a substantial amount of gas demand and allow ramp-up of the gasification project.



Unit	Manufactured	Plate Capacity	Available Capacity
		MW	MW
No. 1	1984	1.74	1.6
No. 2	1985	2.85	2.1
No. 3	1994	2.85	2.1
Total		7.44	5.8

Source: Google and JICA Study Team

Figure 7.3-1 Zuzu Power Station

The power station was installed by Symbion Power Limited in 2011 as an emergency power supply plant when the country was suffering from severe draft and hydropower shortage. The machines are very old and difficult to maintain because spare parts are no more available. The vintage plant may better be replaced with new ones. As Dodoma is receiving most of its power supply from other regions, it may need its own reliable power plant as the country's capital city.

Under the circumstance, we assume that the present Zuzu diesel power plant will be replaced with a combined cycle gas turbine plant. The plant specifications are assumed as follows:

a. Combined cycle gas turbine: 50MW×2units＝100MW
b. Plant factor: 50%
c. Thermal efficiency: 50%
d. Annual LNG consumption: 31,600 ton×2units＝63,200 ton

Currently, electricity demand in Dodoma is around 25MW; it may double in the next decade. As shown in Table 7.1-2, the New Capital City eventually requires 180 MW of electricity supply or 360 MW of generation capacity. Construction of a reliable new power plant is essential to assure stable power supply in this capital city.

As shown in Figure 7.3-1, TANESCO holds a vast land next to the existing power plant and the sub-station. Since solar insolation is ample in Dodoma, TANESCO plans to build a mega-solar plant in this area. Such being the case, a gas driven power plant with very short synchronization time is the most desirable complimentary power source to be packaged with variable renewable power like PV and wind. The capacity of the new gas power plant is optional and may be optimized in consideration of the nation's power system development plan.

7.4 Natural Gas for Automotive Fuel

7.4.1 Macro Projection of Natural Gas Sales as Motor Fuel

Presently there is one experimental NGV project in Dar es Salaam. To introduce NGVs on a grand scale, everything must be prepared from the scratch such as gas supply system, automobile conversion service, technical standards, laws and regulations on safety, environment and economic conditions. It shall be a complex and burdensome procedure. However, if NGVs are introduced successfully, it benefits Tanzania enormously. In addition to providing significant gas demand for developing the gas industry, it will reduce foreign currency outflow for import of petroleum products and GHG emissions replacing them with the less carbon-intensive fuel. As discussed in Chapter 6, gas demand as automotive fuel will be about 50,000 toe in 2025 switching only 1% of the vehicles to natural gas. It will grow to 300,000 toe in 2030 at 5% switching and over one million toe in 2040 at 7% switching. If introduction of NGVs is proved to be viable as project and beneficial for drivers, gas switching will develop much faster from an early stage.

Table 7.4-1 Growth of Motor Vehicles and Natural Gas Demand

	NGVs				Annual Fuel Use			Natural Gas Consumption				
	Tricycle	LPV/ LGV	Truck/ Bus/etc.	Total	Tricycle	LPV/ LGV	Truck/ Bus/etc.	Tricycle	LPV/ LGV	Truck/ Bus/etc.	Total	LNG Equivalent
	(thousand units)				(liter per year per unit)			(thousand tons oil equivalent)				ktons
2015	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	1	1	0	3	1	0	3	0	1	2	3	3
2030	41	52	12	104	52	12	104	6	50	76	132	102
2035	88	126	26	240	126	26	240	14	117	165	296	228
2040	117	368	69	554	368	69	554	21	324	428	774	595
2045	121	793	135	1,049	793	135	1,049	27	662	824	1,513	1,164
2050	111	1,495	232	1,838	1,495	232	1,838	32	1,184	1,395	2,611	2,008

Source: JICA Study Team

To examine viability of introducing NGVs from the view point of fuel cost, we set out hypothetical development scenarios as follows.

7.4.2 Natural Gas Service Station

We assume a model development profile of a typical NGV service station as follows:

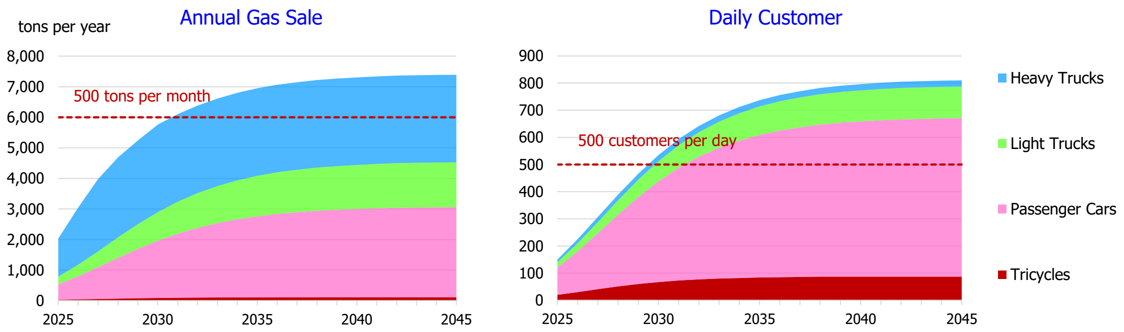
a. The station supplies CNG for tricycles, LPVs (light passenger vehicles) and LGVs (light goods vehicles), and LNG for HDVs (heavy duty vehicles) such as large trucks and buses.

b. For the model gas service station that is the base for the economic evaluation discussed later, standard business size will be of 500 customers per day and sales of 500 tons of natural gas in LNG equivalent per month. The latter compares to a sale of 800 kilolitre (KL) oil products (petrol and diesel) a month, which may eventually increase to 1,000 KL or 700 tons in LNG equivalent.

c. Business will start at 30% of the above model and build up to it in five years. After this point, it continues to expand but at a much slower pace because of its capacity. To accommodate new customers existing stations should be expanded with new investment or new service stations may be built.

Table 7.4-2 Business Development Scenario: Gas service station

	Number of Vehicles per day					CNG				LNG	Total Natural Gas	
	Tricycle Taxi	Passenger cars	Light Goods Vehicles	Heavy Duty Vehicles	Total	Tricycle Taxi	Passenger cars	Light Goods Vehicles	CNG Total	Heavy Duty Vehicles	Annual	Monthly
Starting with	20	100	20	10	150							
2025-2030	27%	30%	30%	18%	29%							
						t	t	t	t	t	t	t
2025	20	100	20	10	150	25	505	253	783	1,246	2,029	169
2026	30	150	30	15	225	38	758	379	1,175	1,869	3,044	254
2027	41	206	41	19	307	52	1,041	518	1,610	2,368	3,978	331
2028	51	264	53	21	389	64	1,334	669	2,067	2,617	4,684	390
2029	60	320	64	22	466	76	1,617	808	2,501	2,742	5,242	437
2030	67	371	74	23	535	85	1,874	935	2,893	2,866	5,760	480
2035	84	525	105	23	737	106	2,652	1,326	4,084	2,866	6,951	579
2040	87	572	114	23	796	110	2,890	1,440	4,439	2,866	7,305	609
2045	87	584	116	23	810	110	2,950	1,465	4,525	2,866	7,391	616
2050	87	587	116	23	813	110	2,965	1,465	4,540	2,866	7,407	617



Source: JICA Study Team

Figure 7.4-1 Natural Gas Sales at Gas Service Station: Model Case

To set out a model scenario, features of natural gas vehicles are assumed as shown in Table 7.4-3.

a. Daily driving distances are 50km for a passenger car mainly for commuting and daily affairs, 100km for local goods delivery, 200km for a taxicab and 300km for long range fleets.
b. Fuel efficiencies are assumed to be same in heat value with petroleum products.
c. Gas storage tanks are in sizes typically designed for NGVs, which are bigger than those for oil driven vehicles.
d. Customers will refill when the fuel tank is 80% empty; anxious people may refill more frequently at a smaller lot.
e. Big trucks for long distance service may prefer to use LNG. They can use CNG, but they need to refill frequently.

Table 7.4-3 Features of Natural Gas Vehicles

		unit	Tricycle Taxi	Passenger cars	Light trucks/ mini-buses	Heavy Duty Vehicles	Heavy Duty Long Range
Driving distance							
Daily		km	200	50	100	100	300
Annual	330 days	km	66,000	16,500	33,000	33,000	99,000
Fuel Milage							
Gasoline	8,000 kcal/ltr	km/ltr	40.00	10.00	8.00		
CNG	13,000 kcal/kg	km/kg	65.00	16.25	13.00		
Diesel	9,100 kcal/ltr	km/ltr				2.00	2.00
LNG	13,000 kcal/kg	km/kg				2.86	2.86
Refueling at 80% empty							
Fuel gas tank(s) on vehicle		liter	30	120	300	1000	1000
Refuelling		liter	24	96	240	800	800
Refuelling	CNG @ 20MPa	kg	3.5	13.8	34.6	115	115
	LNG density@ 0.427	kg				341	341
Distance:CNG		km	225	225	450	330	330
LNG		km				975	975
Frequency: CNG	once per	days	1.12	4.50	4.50	3.30	1.10
LNG	once per	days				9.75	3.25

Source: JICA Study Team

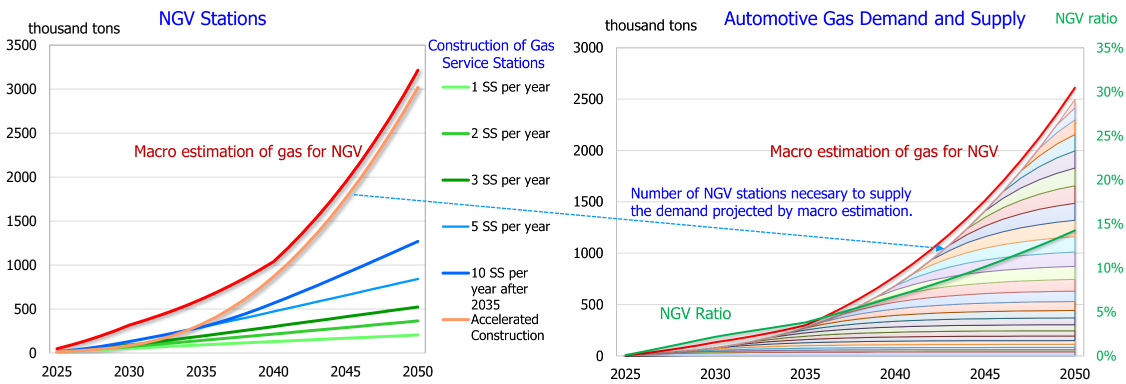
Since natural gas does not ignite automatically even when highly compressed, diesel engines on heavy duty vehicles must be converted with substantial treatment. This will be expensive as discussed later. On the other hand, conversion of light vehicles using petrol is easier and less expensive. Nevertheless, heavy duty vehicles consume more fuel. As shown in the above calculation and Figure 7.4-1 Model Case, gas sales for heavy vehicles exceeds 50% during the initial demand build-up period, though number of them is very small. It should be noted that the composition of gas sales for heavy vehicles starts declining only after the sales enters its plateau period.

7.4.3 Development of Natural Gas Service Station

As discussed in 7.4.1, natural gas consumption as motor fuel is expected to grow fast even with a slight switching of motor vehicles from oil driven to gas driven. To accommodate the increasing demand, a substantial number of gas service station needs to be built. A typical scenario will be as follows:

a. At starting of the project in 2025, two (2) stations may be attached at the sites of satellite terminals in Dodoma, and three more en route from Dar es Salaam.
b. From the next year, additional stations will be built elsewhere gas demand is expected. If the inaugural project is successful, construction will accelerate year by year.

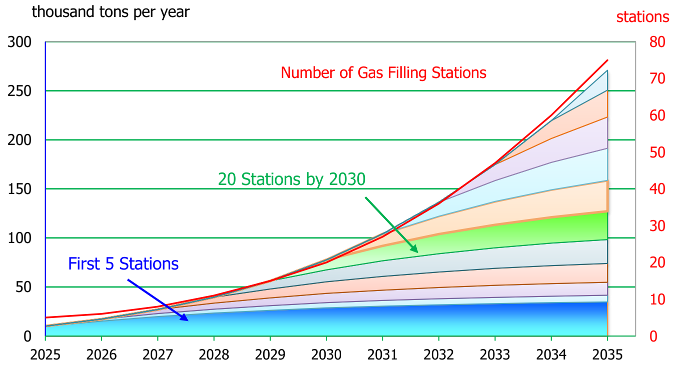
Figure 7.4-2 shows evolution of gas sale along with construction of service stations applying the business profile projected in the previous section. Construction of one or two service stations a year cannot follow the macro estimation as shown on the left chart. The right chart represents the case that the number of new gas stations increases every year, five (5) for 2030, fifteen (15) in 2035 and more in later years. The total number reaches 20 in 2030, 75 in 2035, 180 in 2040 and 540 in 2050; some of them may occur as expansion to a super-giant station. Only in this case, the projected natural gas sale will catch up the macro projection trend as shown in Table 7.4-1.



Source: The JICA Study Team

Figure 7.4-2 Construction of Gas Station and Natural Gas Sale

To consider scenario setting, the early part of the right graph is enlarged in Figure 7.4-3. With the first 5 stations, the total gas sale may stay at around 37,000 tons in LNG equivalent. However, with additional construction of service stations, it will exceed 50,000 tons in 2029 and 100,000 tons in 2031. These calculations suggest that the gas demand for the early project may be in the range of 50,000 -100,000 tons. In the later years when the demand grows faster, gas may be supplied from greater LNG plants and/or by pipelines.



Source: The JICA Study Team

Figure 7.4-3 Number of Gas Stations and Gas Demand

7.5 Distributed Gas Supply for Rural Electrification

If a virtual pipeline system is economically viable, natural gas can also be delivered to energy users in isolated areas and even for rural electrification pending individual demand size and resultant economics.

Just for reference, fuel requirement for a village of 100 households using 2kW of electricity for 10 hours per day may be calculated as follows:

Electricity Demand: 2kW x 10 hours x 365 days x 100 household = 730,000 kWh/year

Fuel Requirement: 730,000 kWh / 35% (fuel efficiency) x 860/10,000,000 = 179 toe (138t LNG)

The fuel requirement in LNG equivalent will be 138 tons a year or delivery of a 18t container once two months. If the rural electrification is run by PV and a gas engine is used only as back-up, energy consumption will be much smaller. Gas engines using indigenous fuel will be beneficial for Tanzania. However, such options are too small at this stage to consider as an effective demand for this project. These options may be considered in the second phase of gasification once viability of this project is established.

7.6 Summary

Incorporating the foregoing analysis, we formulate hypothetical scenarios for gas demand development which comprises:

a. City gas development in Dodoma
b. Large industry users with bulk delivery
c. Gas sale for NGVs

d. Gas switching of the Zuzu power station
e. Introduction of cogeneration (CHP)

Among them, gas demands at the Zuzu power station and CHPs are considered for an optional case. With intensive upfront capital investment, demand build-up in the early stage of the project, in addition to demand size, is important in that it decides how fast the investment can be recovered. Gas demand will grow fast during the build-up stage when new constructions and retrofitting for gas switching progress at users and will slow down in the plateau stage after these activities have matured. Thus, we consider the demand development profile for a model project in two phases.

7.6.1 Gas Demand for Build-up Stage

For the first five years of the project build up stage, we assume that the gas demand will evolve as follows.

1) City Gas in Dodoma

a. New Government City

- Gas demand for office buildings and embassies starts with 500 tons LNG equivalent in 2025 and increases to 1,000 tons in 2030.
- Gas demand in the commercial sector starts with 1,500 tons in 2025 and grows to 3,400 tons in 2030.
- Gas demand in the residential sector starts in 2025 at 50 tons and increases to 100 tons in 2030.
- As an optional case, gas demand for CHPs for office buildings, embassies, shopping malls, and hotels starts with 10,000 tons LNG equivalent (for 4 units) in 2025 and increases stepwise to 20,000 tons (for 8 units) in 2030 as large buildings are being built.

b. Dodoma City Centre

- Gas demand for office buildings starts with 500 tons in 2025 and increases to 1,000 tons in 2030.
- Gas demand in the commercial sector starts with 1,500 tons in 2025 and increases to 3,000 tons in 2030.
- Gas demand in the residential sector starts with 1,500 tons (for 15,000 people) in 2025 and grows to 3,000 tons in 2030.
- As an optional case, gas demand for CHPs for office buildings and hotels starts with 4,000 tons (for 2-4 units) in 2025 and increases to 9,000 tons (5-8 units) in 2030.

c. Iyumbu Satellite Centre

- No gas demand for office buildings.
- Gas demand in the commercial sector starts with 200 tons in 2025 and increases to 500 tons in 2030.
- Gas demand in the residential sector starts with 200 tons (for 2,000 people) in 2025

and increases to 500 tons in 2030.

- As an optional case, gas demand for CHPs for office buildings, shopping malls, and hotels starts with 600 tons (one unit) in 2025 and increases to 1,500 tons (3 units) in 2030.

2) Gas demand as direct bulk delivery for large factories and Gas Grids in other cities starts with 15,000 tons in 2025 and increases to 20,000 tons in 2030.
3) Gas sale at the first five (5) gas stations is considered with the development pattern discussed in the previous section though more stations may be built if they are viable.
4) As an optional case, gas demand for the Zuzu power plant starts with 31,600 tons in 2025 and increases to its plateau of 63,200 tons in 2030.

These projections are summarized in Table 7.6-1 and Figure 7.6-1.

Table 7.6-1 Gas Demand Development Scenario

		2025	2026	2027	2028	2029	2030
City Gas		(in LNG tons)					
Plan-A NGC	Office Building	500	600	700	800	900	1,000
	Commercial Facility	1,500	1,880	2,260	2,640	3,020	3,400
	Household	50	60	70	80	90	100
	Sub-total	2,050	2,540	3,030	3,520	4,010	4,500
Plan-B City Centre	Office Building	500	600	700	800	900	1,000
	Commercial Facility	1,500	1,800	2,100	2,400	2,700	3,000
	Household	1,500	1,800	2,100	2,400	2,700	3,000
	Sub-total	3,500	4,200	4,900	5,600	6,300	7,000
Plan-C Iyumbu	Office Building	0	0	0	0	0	0
	Commercial Facility	200	260	320	380	440	500
	Household	200	260	320	380	440	500
	Sub-total	400	520	640	760	880	1,000
Total		5,950	7,260	8,570	9,880	11,190	12,500
Direct Delivery		15,000	16,000	17,000	18,000	19,000	20,000
NGV First five Stations		10,100	15,200	19,900	23,400	26,200	28,800
Options							
Zuzu Power Station		31,600	37,920	44,240	50,560	56,880	63,200
CHP	NGC	10,000	12,000	14,000	16,000	18,000	20,000
	City Centre	4,000	5,000	6,000	7,000	8,000	9,000
	Iyumbu	600	780	960	1,140	1,320	1,500
	Sub-total	14,600	17,780	20,960	24,140	27,320	30,500
Model Scenarios							
Case-A	Plan-A + Direct Delivery + NGV	27,150	33,740	39,930	44,920	49,210	53,300
Case-B	All but excluding CHP	62,650	76,380	89,710	101,840	113,270	124,500

Source: JICA Study Team

Figure 7.6-1 Gas Demand Development Scenario: Early Stage

7.6.2 Long Term Demand Growth and Scenarios for Case Study

After five years of the build-up period, gas demand for the first project will reach a plateau stage though continue to grow but at a slower speed. As demand will come closer to the supply capacity sooner or later and the service areas will be expanded, additional investment for the projects will be considered. We assume the long-term demand profile for the first project as below:

a. Gas demand growth at the Iyumbu Satellite Centre slowdowns to annual 2% as the city development matures.
b. City gas demand at NGC and city centre will grow at annual 5% with expansion of service areas and increase in penetration ratio.
c. Just as an interim assumption for project evaluation, number of gas service stations for NGVs remain at five (5). However, NGVs may possibly penetrate fast once its introduction policy is launched successfully.
d. Gas consumption at the Zuzu power station remains at the same level

For economic evaluation of a gasification project, we assume the following two scenarios:

Case-A: A city gas system will be constructed only at the New Government City. Natural gas will be delivered to the NGC, direct bulk users and four gas stations to serve for NGVs. The total demand may allow construction of two trains of 100 tons in LNG equivalent per day plant. The gas plant will reach its full operation around 2035.

Case-B: Three city gas systems will be set up at the city centre and Iyumbu in addition to the NGC. Natural gas will also be delivered to bulk users, five gas stations and the Zuzu power station. The total demand may allow construction of two trains of 200 tons per day plant.

Table 7.6-2 Long Term Gas Demand Scenario

	City Gas				Bulk Delivery	NGV First 5 SS	Zuzu Power Station	Case-A		Case-B		CHPs not included
	NGC	City Centre	Iyumbu	Total				NGC+Bulk+NGV SS		Case-A+Zuzu PS		
	t	t	t	t	t	t	t	t	t/day	t	t/day	t
2025	2,050	3,500	400	5,950	15,000	10,100	31,600	27,150	82	58,750	178	14,600
2030	4,500	7,000	1,000	12,500	20,000	28,800	63,200	53,300	162	116,500	353	30,500
2035	5,700	9,000	1,100	15,800	25,600	34,800	63,200	66,100	200	129,300	392	31,970
2040	7,200	11,600	1,200	20,000	32,700	36,500	63,200	76,400	232	139,600	423	33,530
2045	9,200	14,800	1,320	25,320	41,700	37,000	63,200	87,900	266	151,100	458	35,160
2050	11,800	18,900	1,470	32,170	53,200	37,000	63,200	102,000	309	165,200	501	36,880

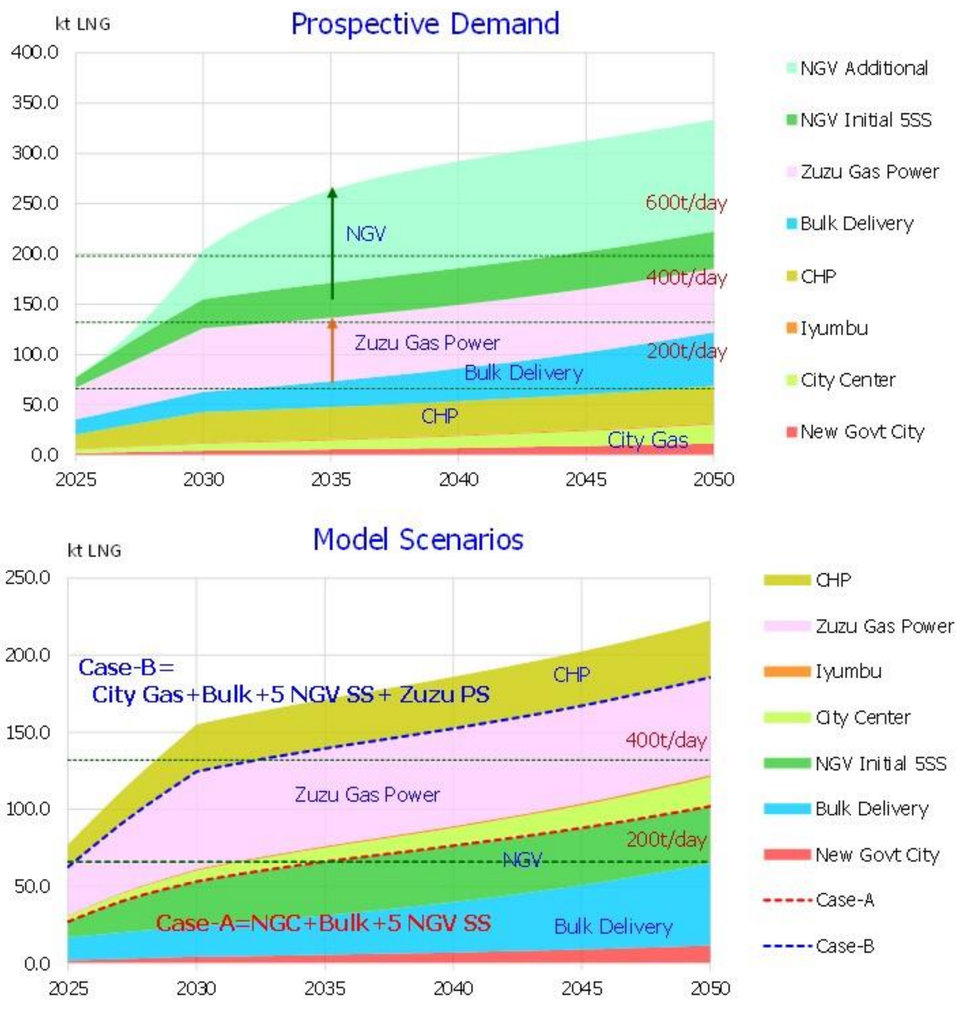
Source: JICA Study Team

7.6.3 Issues to Note

The above Case-A and Case-B will be used for the analysis to examine comparative economics of LNG, CNG and pipeline as mode of gas transport although there are many uncertainties. To ensure such scenarios, high level decisions must be made on implementation of the following policies:

a. City gas development in Dodoma
b. Introduction of NGVs
c. Gas switching of the Zuzu power station

On the other hand, fuel switching at large industrial and commercial users may be sought more or less on commercial basis. At any rate complex preparatory work is necessary to establish an institutional platform to implement the above policies.



Source: JICA Study Team

Figure 7.6-2 Long Term Gas Demand Development Scenario

Major uncertainties anticipated in the above scenarios are as follows:

1) With a prospect that Dodoma as the capital city will develop robust, it is assumed that city gas systems will be introduced there proactively. This is just a draft grand design yet to be endorsed. City gas as handy and clean fuel will bring significant benefit to the human life and the society, but it has to compete with traditional fuels such as firewood and

charcoal as well as emerging LPG. It must be affordable fuel. In view of the high upfront expenditure for inlet pipe connection, city gas penetration might be slower.

2) Introduction of NGVs requires a great challenge to reform the country's automotive policy engaging multiple sectors such as automobile technical service and fuel supply system. On the other hand, if NGVs are introduced on a grand scale, the natural gas demand picture will be totally changed as shown on the left chart of Figure 7.4-2.

3) As discussed later, natural gas may be a preferable fuel for the Zuzu power station compared with diesel gas oil presently used there. However, its gas switching is another matter to be reviewed from the view point of the overall power supply system.

4) In the above case setting, CHPs are not included considering the mild weather in Dodoma and relatively low electricity tariff obtained from the grid. However, CHP with gas provides high energy efficiency and lower emissions. If they are introduced, it will provide considerable anchor demand for development of city gas system.

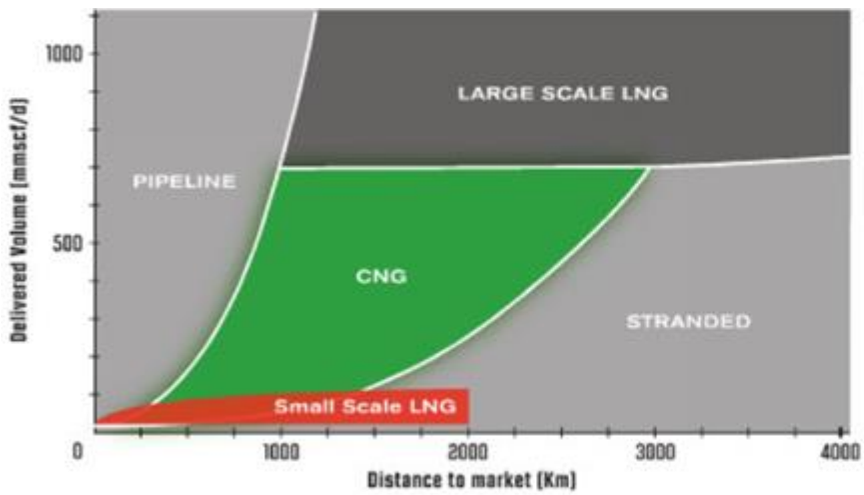
All in all, Case-A and Case-B scenarios as shown on the bottom chart of Figure 7.6-2 are used to examine viability of virtual gas project although the components of the demand would be reshuffled.

Chapter 8 Natural Gas Supply Systems

In this Chapter, various measures available for delivering natural gas to the Tanzanian domestic energy market are discussed, along with an overview of gas transportation and delivery systems and their technical features as well as challenges. The relevant cost study and economic analysis on the desirable systems will be discussed in Chapter 9.

8.1 Natural Gas Supply Systems and Virtual Pipeline

Pipeline is the method which is technically most simple and easy to transport natural gas and thus it has been used for long time. However, pipeline is not always a commercially feasible option because of its specific features to impact economics such as the requirement for a certain size of project scale, a large upfront capital expenditure, and the inflexibility in operational capacity. When natural gas needs to be transported inland, if the terrain of the route is gentle, pipeline would be a favourable option depending on the volume of the delivered gas and transport distance. However, pipeline is not necessarily a feasible option for gas transport in the case of small volume and/or long-distance. This is especially true if it involves subsea transport. Natural gas can be delivered by changing its form, namely, to liquefied (= LNG) form or compressed (= CNG) form, according to transport efficiently. Figure 8.1-1 shows comparative superiority in economics for LNG, CNG and pipeline in relation to gas transport volume and distance to the market. This chart indicates that pipeline will be preferred if gas volume is large and distance is short but small scale LNG or CNG may be preferred if demand is small and distance is longer.

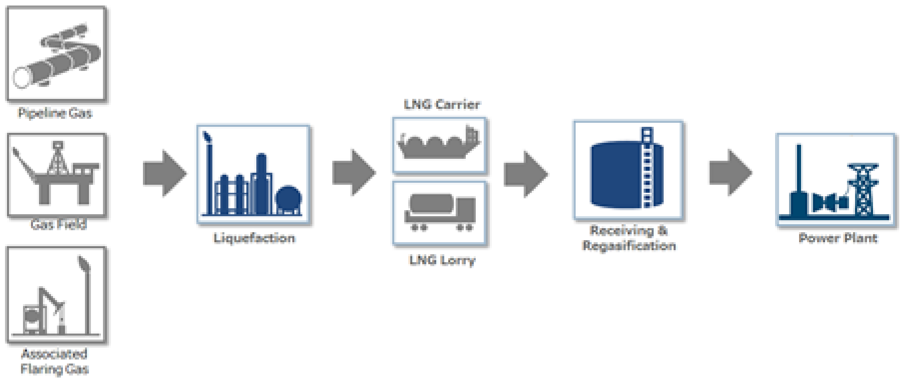


Source: VNB Enterprises HP

Figure 8.1-1 Natural Gas Transportation by LNG, CNG or Pipeline

In the case of small volume transport, LNG or CNG will be delivered by trucks, rail tank wagons or ships to the terminal near the demand point and then regasified or decompressed to natural gas for delivery to final users. Since such a supply chain resembles a pipeline system, even though it is not a real pipeline; it is called a *Virtual Pipeline*. Virtual Pipelines are the substitutes for real pipelines that distribute gas via land or sea transport. They replicate the continuous flow of energy between disconnected points via transport logistics using trucks, rails or ships as shown in Figure 8.1-2.

In order to make natural gas available for use by final consumers such as households, industries and commercial and public facilities, it is necessary to develop gas transport and supply systems linking its sources and final users. City gas pipeline networks connected to the consumption points or dedicated cylinders filled with natural gas would be the possible options to distribute natural gas to such end users.



Source: JICA Study Team

Figure 8.1-2 Image of Virtual Pipeline (LNG case)

With regard to the future gas demand and possible gas market development path in Tanzania, the following options for gas transport are examined as possible solutions. Outline of these options and related considerations are discussed in section 8.3.

1) Mini LNG
2) CNG
3) DME
4) GTL/LPG
5) Study of the gas transport pipeline
6) Considerations on LPG import and transport

8.2 Transport Systems in Tanzania

Tanzania is a vast continental country extending 1,260 km north-south and 1,200 km east-west with a total land area of 947,303 km^2. Thus, land transport is a key issue for its economic development as well as neighbouring interior countries. Presently road transport is the dominant mode which accounts for over 80% of passenger traffic and over 95% of freight traffic. Because of its limited capacity and service, rail freight transport has been declining for decades. Aviation and maritime services are still tiny but are expected to expand significantly in the future. In addition, a crude oil pipeline from Tanzania to Zambia is in operation, the new natural gas trunk pipeline from Mtwara to Dar es Salaam is now operational, and the East African Crude Oil Pipeline (EACOP) is going to be built from Uganda to Tanga and for further export from there. Also, an ambitious gas pipeline plan was signed in April 2021 to deliver natural gas from Tanzania to Mombasa, Kenya; the pipeline extends for 600km at a cost of US$1.1 billion.

In order to support economic development, several important infrastructure projects are planned wherein some of them are being implemented as below:

a. Construction of electrified Standard Gauge Rail (SGR) running from Dar es Salaam (DSM) to Morogoro, Dodoma, and eventually Mwanza. The Dar es Salaam to Morogoro phase (205km) is planned for commission in late 2021.
b. Improvement of road and rail access to the port of DSM by building an integrated multi-modal transport system including upgrading of the port facility, construction of the DSM-Chalinze Expressway (144km) and the Ruvu Dry Port.

Above upgrading of the transport infrastructure is essential to enable the “Virtual Pipeline” concept as a means to transport natural gas to smaller and/or independent gas users economically and efficiently.

8.2.1 Railway Sector

(1) Narrow Gauge Lines and Improvement Plan

Presently, the total national railway network in Tanzania extends 3,682km of trunk lines, out of which 2,707km are traditional meter gauge (1,000mm) operated by Tanzania Railways Ltd. (TRL: formerly known as TRC), and 975km are narrow gauge (1,067mm) operated by Tanzania-Zambia Railway Authority(TAZARA)[51]. Out of the 2,707km of the TRL operated network lines, 2,126km (79%) are presently operational, namely:

a. Central Line: from Dar-Kigoma via Tabora and Kaliua of 1,251 route-km;
b. Mwanza Line: from Tabora-Mwanza via Isaka of 379 route-km;
c. Link-Line: from Muruazi Junction to Ruvu Junction of 188 route-km;
d. Tanga-Korogwe Line of 98 route-km; and
e. Mpanda Line: from Kaliua to Mpanda of 210 route-km.

However, as the facilities are old and services are poor, railway has been losing its business to road transport. Tanzania being a land country, however, it is strategically important to revitalize its railway systems by constructing strong backbone lines to strengthen the flow of commodities and materials throughout the country to support the country’s economic development and enhance trade with countries in hinterland. Accordingly, the country had set aside $US 500 million for the project and tried to secure soft loans.

[51] RELI Assets Holding Company Limited (RAHCO), “11th Joint Transport Sector Review (JTSR2017)”

Box: Restructuring of Railway System from TRC to TRL

In order to reverse the deteriorating trend of the rail industry, which was constructed since 1905 as the second railway project in the then colony of German East Africa, state-owned Tanzania Railways Corporation (TRC) was decomposed and Tanzania Railways Limited (TRL) was established in 2007 as a private company jointly owned by the Government of Tanzania (GOT) (49% shares) and RITES of India (51% shares). Before establishment of TRL, the central railway line was run by the TRC since 1977. To facilitate the new system, state owned Reli Assets Holding Company (RAHCO) was established in 2002 with a mandate to promote, develop, manage and maintain rail infrastructure and to provide rail transport services through joint venture, concession and the like. RAHCO, being mandated by the Railway Act, 2002, has delegated its powers of providing rail transport services to Tanzania Railways Limited (TRL). However, decline in traffic continued and the government bought back the share of RITES in 2011, while TRL continued railway operation. The Railway Act 2017 was passed by the parliament in September 2017, and the process of forming a new railway institution by the name of Tanzania Railway Corporation (new TRC) is underway, which will consolidate management of infrastructure and operation.

(Source: Tanzania Railway Limited website, http://www.trl.co.tz/, and others)

Under this policy, the government has started construction of Standard Gauge Railway for the Dar es Salaam – Morogoro (300km) and Morogoro – Makutupora (north of Dodoma:422km) sections. Contractors are currently on site for construction of two sections while Government is soliciting funds for implementing the remaining sections of Makutupora – Tabora (249km), Tabora – Isaka (133km) and Isaka – Mwanza (249km). The new standard gauge railway will be constructed parallel to the existing one-meter gauge track line along the central corridor. The strategy is for the standard gauge railway to facilitate freight traffic to the hinterland and to the neighbouring land linking Uganda, DRC, Rwanda and Burundi while the existing meter gauge continues supporting domestic freight and passenger traffic in remote areas of the mainland.

More importantly, Tanzania Intermodal and Rail Development Project (TIRP) is planned, which aims to provide a reliable open access infrastructure on the existing narrow gauge rail segment between Dar es Salaam and Isaka (970km). The project has four components as shown in Table 8.2-1.

Table 8.2-1 Components of the Project with Budget Estimate

Component Name	Cost(USD Millions)
Component A: Improvement of Rail Infrastructure	232.5
Component B: Rolling Stock	19.3
Component C: Development of Isaka Terminal, Ilala Goodshed and Dar es Saaam Port Platform	15.3
Component D: Institutional Strengthening, Capacity Building and Implementation Support	32.9
Total	**300.0**

Source: JICA Study Team

Figure 8.2-1 Railway in Tanzania: Existing System and Future Plan

The Project focuses on the rehabilitation of the Dar es Salaam – Isaka section of the central railway line to achieve a minimum permissible axle load capacity of 18.5 tonnes per axle. To achieve this, the Project proposes to:

a. Re-lay within the project areas between DSM-Munisigara (308km) and Igalula- Tabora (39km) with 80 Lbs. track material;
b. Rehabilitation of weak bridges to increase the capacity to a minimum of 18.5 tonnes per axle load;
c. Train control system for controlling train movement safety;

d. Purchase of 3 new locomotives, 44 flatbed wagons, and remanufacturing of locomotives;
e. Strengthening Capacity measures for project implementation to TRL, RAHCO, SUMATRA, and MoWTC.

Among others, construction of the SGR will involve the use of highly advanced technology and power which will enable to increase: a) speed of train from 30km/h as of now to 160km/h, and b) axle load from 13 tonnes to 35 tonnes.

Current status of the project is as follows:

(i) Infrastructure:

Package A: Dar es Salaam-Kilosa (283km and 122 bridges)

- Bids for rehabilitation of track and bridges for package A were invited on 1st June 2017 and opened on 20th September 2017 and China Civil Engineering Construction Corporation won the bid.
- Procurement of consultant for supervision of package A is ongoing and has reached an advanced stage which is combined Technical and Financial evaluation.

Package B: Kilosa-Isaka (687km and 270 bridges)

- Bids for rehabilitation of track and bridges were invited on 4th October 2017 and expected to be opened on 22nd November 2017 and China Civil Engineering Construction Corporation won the bid.
- Procurement of consultant for supervision of bridges and track rehabilitation for package B is ongoing and has reached an advanced stage which is combined Technical and Financial evaluations

(ii) Design and upgrading work on Intermodal Exchange Terminals of Dar Port rail layouts, Ilala Yard and Isaka ICD's is ongoing and expected to be completed in November 2017.

Current status of the new SGR line is as described below:

- Design and Build contract of US $1.2 billion for construction of Dar es Salaam - Morogoro (205km) was signed on 3 February 2017 between RAHCO and Joint venture of YAPI MERKEZI (TURKEY) MOTA-ENGIL (PORTUGAL).
- The work is 92.7% complete in summer 2021. 42 electric locomotives will be delivered in November and training of engineer will start.
- Design and Build contract for Morogoro-Makutupora (336km) has been signed on 29th September, 2017 between RAHCO and contractor YAPI MERKEZI (TURKEY). The work is ongoing.[52]
- Soliciting funds by the GoT for construction of other lots, from Makutupora – Tabora (249km), Tabora – Isaka (133km) and Isaka – Mwanza (249km) is ongoing.

[52] https://www.youtube.com/watch?v=-C7JZvJvdaQ

(2) TAZARA

Apart from the traditional railway system, the TAZARA railway extending for 1,860km, was built in 1970-1975, supported by China amid the southern African turmoil to provide a new route for Zambia's copper belt to reach the seaport without crossing the white-ruled territories.

The TAZARA has a track gauge of 3ft 6 in (1,067 mm), also known as the Cape Gauge, which is widely used throughout southern Africa. The TAZARA connects to the Cape-gauge Zambia Railways at Kapiri Mposhi. Rovos Rail of South Africa operates the Pride of Africa, a luxury train that runs periodic tours from Cape Town to Dar es Salaam via the TAZARA. Commuter train service on the TAZARA between Dar es Salaam and its suburbs commenced in 2012 As above, the remainder of Tanzania's railways have 1,000 mm (3ft 3 3⁄8 in) meter gauge tracks. A transhipment station with a break of gauge station was built in Kidatu in 1998 in the south of Morogoro connecting to the traditional line.

TAZARA's freight traffic peaked at 1.2 million tonnes in 1986. However, independence of Namibia in 1990 opened an alternative shorter transport route to the sea for Zambia's copper ore export and freight traffic drastically decreased to 88,000 tonnes in 2014/15 fiscal year, or down to less than 2% of its capacity. Recently Governments of Tanzania and Zambia have agreed to review TAZARA Act No.4 of 1995 so as to address the legal bottlenecks for the transformation of TAZARA and make it commercially viable by improving business environment and operational efficiency including involvement of the private sector. Redevelopment plan for TAZARA is yet to be drafted.

(3) Long-term Development Plan

In the long run, RAHCO proposes a Strategic Targets to establish three corridors, namely Central, North and South corridors as depicted in Figure 8.2-2. It aims to establish a) railway network linking northern territories and neighbouring countries and b) a new system to ship rich mineral resources presently land-locked in the southern interior regions.

a. Construction of Central Standard Gauge Railway Line (Central Corridor)

The Government is underway for the development of the Central Railway Network to standard gauge. The proposed project will be the vital artery of the economy and serve the central part of the country, North West and the neighbouring countries of Uganda, Rwanda, Burundi, DRC and Zambia. The entire railway network planned for development to standard gauge is 2,561 km and its project network lines components are:

a) Dar es Salaam - Isaka-Mwanza (1,219km),
b) Tabora - Uvinza - Kigoma (411km),
c) Kaliua – Mpanda - Karema (321km),
d) Isaka - Rusumo (371km),
e) Keza - Ruvubu (36km); and

f) Uvinza - Kalelema towards Musongati (203km).

At present construction for the lot one from Dar es Salaam to Morogoro (205km) is almost complete, and the construction for the lot two from Morogoro to Dodoma is ongoing. Fund securing process is underway for construction of other lots, from Dodoma (Makutupora) – Tabora (249km), Tabora – Isaka (133km) and Isaka – Mwanza (249km).

b. Northern Corridor (Northern Railway Line) Tanga – Arusha – Musoma with spurs to Engaruka and Minjingu Railway Project

The standard gauge railway line will traverse northern Tanzania corridor from Tanga to Arusha (438km) on the existing Right-of-Way (RoW) to replace the existing meter gauge and then extend in a green field to Musoma port in Lake Victoria (about 600km) with spurs to Engaruka soda ash mine and Minjingu phosphate mine, the total length will be 1,108km.

At present, Detail Design of Tanga to Arusha and Feasibility Study and Preliminary Design for Arusha to Musoma section are completed.

c. Southern Corridor – Mtwara – Songea – Mbamba Bay with spurs to Liganga and Mchuchuma

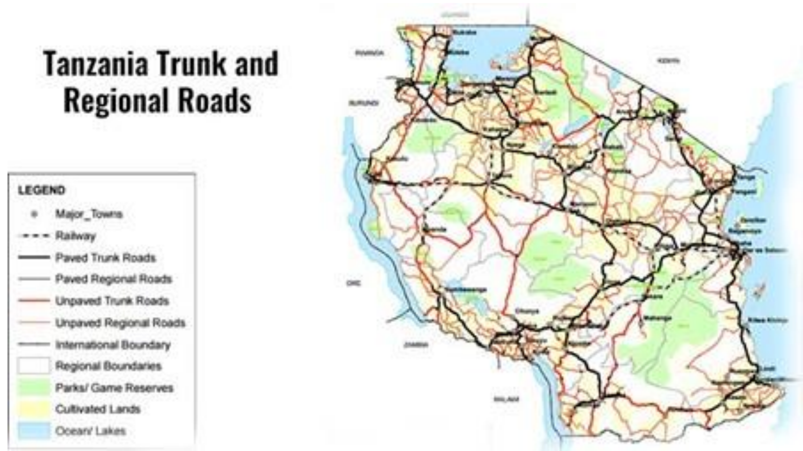
Geographically, the Southern Corridor is designed to cover and link the Southern regions of Tanzania, Northern Mozambique, Northern and Central Malawi, Eastern and Northern Zambia. The Southern railway corridor of 1,000 km will provide connectivity from Mtwara Port to Mbamba Bay in Lake Nyasa, Liganga Iron Ore fields and Mchuchuma coal mines west of Mtwara Port.

At present, Feasibility Study and Preliminary Design have been completed. Preparation of tender documents for engaging transaction advisor is underway. Under the current circumstance, construction of the standard gauge railway from Dar es Salaam to Dodoma, which has already started, will provide a realistic option of a virtual pipeline system for the DNGPP Study. As the modernisation of the railway system progresses nationwide, natural gas can be delivered to more remote areas via a multi-modal virtual pipeline system.

8.2.2 Road Sector

(1) Overview of Road System and its Network in Tanzania

Road system is the main transportation network in Tanzania since its land area is large and railway system is still in the developing stage. As of June 2016, the length of major road network in Tanzania was 35,000km, including 12,786km of trunk roads and 22,214km of regional roads. Road system maintenance and construction is under the control of Tanzania National Roads Agency (TANROADS), a semi-autonomous agency of the Ministry of Works, Transport, and Communications (MOWTC). Since its establishment in June 2017, Tanzania Rural and Urban Roads Agency (TARURA) has been assigned with the maintenance work of regional roads from local governments.



Source：http://www.tanzaniainvest.com/wp-content/uploads/2016/11/tanzania-roads-network.jpg

Figure 8.2-2 Tanzania Trunk and Regional Roads

Table 8.2-2 Road System in Tanzania

Road Type		Length (km)	Total Length (km)
Trunk	Paved	7,773	12,786
	Unpaved	5,013	
Regional	Paved	1,433	22,214
	Unpaved	20,781	
Total		35,000	35,000

Source: TANROADS Paper for Eleventh Joint Transport Sector Review (JTSR) Meeting, p, 2.

Road system in Tanzania can be divided into 5 categories, namely trunk roads, regional roads, district roads, feeder roads, and urban roads. Tanzania's road system supports domestic transportation and logistics that contribute to its economic growth. The road system is also developed beyond country's border and is connected to the East African Community (EAC)'s network such as Kenya and Uganda. Geographically, Tanzania is the main gate of logistics for landlocked countries such as Uganda, Rwanda, Burundi, Congo, Zambia, and Malawi. Therefore, it can be said that road system development is also the key for regional economic development. Major corridors of EAC through Tanzania are as below (Note: **Bold** is used to indicate cities in Tanzania)[53]:

a) Central Corridor: Dar es Salaam – Morogoro – Dodoma – Singida – Nzega – Nyakanazi – Burundi - Kigali - Gisenyi (3,100km)
b) Dar es Salaam Corridor: Morogoro – Iringa – Mbeya - Tunduma (1,100km)
c) Namanga Corridor: Iringa – Dodoma – Kalema – Arusha – Nairobi – Thika – Muranga – Embu – Nyeri – Nanyuki – Isiolo – Marsabit - Moyale (1,800km)
d) Sumbawanga Corridor: Tunduma – Sumbawanga – Kasulu – Makamba – Nyanza – Lac – Rumonge - Bujumbura (1,300km)

[53] JICA (2014) Comprehensive Transport and Trade System Development Master Plan in the United Republic of Tanzania, p. 4-1.

e) Sirari Corridor: Lokichokio – Lodwar – Kitale – Bungoma – Kisumu – Kisiji – Mwanza - Biharamulo (1,500km)
f) Coastal Corridor: Mingoyo - Dar es Salaam – Chalinze – Vanga – Mombasa – Malindi - Lamu (1,500km)
g) Mtwara Corridor: Mtwara – Mingoyo – Masasi – Tunduru - Songea-Mbamba Bay (800km)
h) Arusha Corridor: Arusha – Moshi – Himo – Lushoto – A1 (500km)

In general, road system in Tanzania is still developing while pavement condition needs to be improved. As of June 2017, the length of paved roads in Tanzania reached 9,206km and 47% of their condition was evaluated as "Fair", followed by 40% of "Good."[54] Since 2002, road conditions have been improved along with the Ten-Year Road Sector Development Programme as development of trunk road was given investment priority[55]. On the other hand, construction and maintenance work on regional roads are significantly delaying behind. Since railway transportation service is not popular in Tanzania due to the poor system condition, road system mainly provides logistics leading to increases in traffic volume as well as the number of heavy vehicles on road. Thus, such conditions are causing substantial damages to the road conditions and incurring the rise in the maintenance cost.

Regarding budget and fund for the road sector, TANROADS has no authority to control the budget for road construction and maintenance but uses national budget as well as international aids from international organizations, development funds and oil producing countries[56]. The Tanzanian government transfers revenues from gasoline tax to special fund for road rehabilitation and maintenance. According to the official data, up to about 80% of the budgeted renovation and maintenance work plans for trunk road is achieved whereas the rate is merely 30% for regional roads. Under the circumstance, it is pointed out that there are significant delays in maintenance programmes due to budget constraints and unpaid or delayed wage payment by the contractors.

(2) Long-term Development Plan for Road Sector

Road system development has been given certain priority in order to promote socio-economic development in Tanzania. TANROADS implements construction and maintenance programmes along with annual plans based on Vision 2025, Five Year Development Plan, National Transport Policy, and Transport Sector Investment Program (TSIP).

In 1999, Tanzanian Government launched the Vision 2025 that attempts to make the nation graduate from a developing country to a middle-income country. Under the Vision, the government has implemented economic and social development programmes emphasising that

[54] Tanzania National Roads Agency (2017) TANROADS Paper for Eleventh Joint Transport Sector Review (JTSR) Meeting, p, iv.
[55] African Development Bank (2013) *Tanzania Transport Sector Review*, p. 33.
[56] Tanzania National Roads Agency (2017) *TANROADS Paper for Eleventh Joint Transport Sector Review (JTSR) Meeting*, p, 2.

"the development of the road network is absolutely essential for promoting rural development". However, through reviews of the Vision, it was pointed out that poor economic infrastructure, especially in the transportation sector, is the bottleneck for Tanzania's comparative advantage in the region and international trade. Thus, the new national development plan calls for further investments for electricity and transportation sectors to improve their quality[57].

Table 8.2-3 Completed feasibility studies and detailed design which require funds for rehabilitation/upgrading by 2017

	Name of the Project	Length (Km)	Estimated Cost (Million USD)
Rehabilitation Project	Nayanguge-Magu-Musoma	85	77
	Mtwara-Masasi Road	200	180
	Makambako-Songea Road	295	266
	Same-Himo-Marangu and Mombo-Lushoto Projects	132	120
	Lusahunga-Rusumo Road Project	92	83
	Kobero-Nyakasanza	58	52
	(Total)	862	778
Upgrading Projects	Makurunge-Saadani-Pangani-Tanga	178	142.4
	Tabora-Koga-Mpanda	363	-
	Mbinga-Mbamba Bay	67	-
	Makongolosi-Rungwa-Itigi-Mkiwa	277	249.5
	Nyahua-Chaya	85	-
	Urambo-Kaliua	28	-
	Kazilambwa-Chagu	36	32
	Uvinza-Ilunde-Malagarasi	51	46
	Kidahwe-Kasulu/Mugina-Nyakanazi	250	225
	Mpanda-Uvinza-Kanyani (Kasulu)	141	126
	Kibaoni-Sitalike (Katavi)	74	67
	Lolindo-Mugumu-Natta Road	131	118
	Bomang'ombe-Sanya Juu-Kamwanga	68	61
	Kyaka-Bugene/Benako Road, Bugene-Benako Section	124	99.2
	Handeni-Kiberashi-Kwamtoro-Singida	461	369
	Musoma-Makoji-Busekela Road	92	73.6
	Kisarawe-Mlandizi Road	119	95.2
	(Total)	2,545	1703.9

Source: Tanzania National Roads Agency (2017) TANROADS Paper for Eleventh Joint Transport Sector Review (JTSR) Meeting

The National Transport Policy set up several goals for the transport sector development to achieve economic development of Tanzania. Regarding road system, it focusses on paving all trunk roads linking regional capitals to bitumen standard by 2018 to address high transport costs and access restrictions attributable to sector inefficiencies . By 2017, TANROADS completed feasibility studies and detail design for rehabilitation and upgrading programmes as shown in Table 8.2-3. However, there is no financing commitment for half of the projects while the rest are committed by Government of Tanzania, African Development Bank, Kuwait Fund, Abu Dhabi Development Fund as well as OPEC Fund. Over the next 3 years, TANROADS plans to implement road maintenance and development programmes. For the maintenance work

[57] African Development Bank (2013) Tanzania Transport Sector Review, pp. 22-23.

programme of FY 2017/18, 78% of budget or TZS 444 billion is allocated for trunk and regional roads maintenance. For Development Programme for FY 2017/18-2019/20, Table 8.2-4 shows that 44% of the budget both approved and estimated are funded by development partners although Tanzanian Government attempts to allocate budget through Road Fund. It is important for implementation of maintenance and development plans to secure sufficient budget and its efficient use.

Table 8.2-4 Road Development Budget for FY 2017/18-2019/20

Project Description	Approved Budget for FY 2017/18		Budget Estimates for FY 2018/19		Budget Estimates for FY 2019/20	
	Local (TShs Million)	Foreign (TShs Million)	Local (TShs Million)	Foreign (TShs Million)	Local (TShs Million)	Foreign (TShs Million)
Trunk and Regional Roads	606,655.00	469,213.79	679,453.60	525,519.45	760,988.03	588,581.78
Total	1,075,868.79		1,204,973.05		1,349,569.81	

Source: Tanzania National Roads Agency (2017) TANROADS Paper for Eleventh Joint Transport Sector Review (JTSR) Meeting,

In addition to the above projects, there are several road development and maintenance programmes financed by international donors. World Bank is currently providing funds for three major road related projects, namely the Transport Sector Support Project (TSSP) which will concentrate rehabilitation of various paved and trunk roads, the Southern Africa Trade and Transport Facilitation Project which rehabilitate and upgrade the Mafinga-Igawa road section of the Dar es Salaam Corridor, and the Tanzania Development Corridors Project which aims to improve transport connectivity of corridors in Tanzania. In addition, the African Development Bank also finances road sector upgrading programmes to boost the agriculture sector[58].

8.2.3 Port Sector

Maritime trade is one of the key sectors for economic development of Tanzania since it relies on imports of commodities including gasoline and LPG. Being the gateway to Tanzania, the port sector is always connected with other transportation sector such as roads and railways. In the future, it may become possible to transport Tanzanian LNG by domestic vessels from the producing areas to consumption areas as well as export LNG from main ports of Tanzania to nearby international markets.

There are several major and smaller sea ports in Tanzania, which are located at Dar es Salaam, Tanga, and Mtwara while smaller sea ports are at Kilwa, Lindi, Mafia, Pangani, Bagamoyo, and Mikindani[59]. Major sea ports are managed and operated by the Tanzania Ports Authority (TPA)[60]. Among them, the port of Dar es Salaam has the largest capacity handling 10 million tonnes of

58 Ministry of Works, Transport and Communication (2017) *Eleventh Joint Transport Sector Review* (JTSR 2017), pp.14-18.
59 African Development Bank (2013) *Tanzania Transport Sector Review*, p. 64.
60 Ministry of Works, Transport and Communication (2017) *Eleventh Joint Transport Sector Review* (JTSR 2017), p. 7.

cargoes in 2010/11[61]. The port can receive vessels of up to 9.4m draft and 200m in LOA, with 11 berths operated by TPA[62]. Cargo traffic has been increasing at an annual 8% between 2006 and 2010 thus the port capacity expansion is an urgent issue.

Port of Tanga is located in the northern Tanzania that is the logistics gate for a major city Arusha and famous tourist site of Kilimanjaro. It has a long history, but the port size remains small compared with other major sea ports in the region such as Dar es Salaam and Mombasa in Kenya. However, the port of Tanga is now attracting attentions in the energy market as it was selected as the crude oil export port for the 1,445km long Uganda-Tanzania Crude Oil Pipeline (UTCOP) project that reached an agreement in 2017. As the water depth of the Tanga port is limited, it has remained as a lighterage port. Therefore, although there are several berths to handle cargos, port capacity is limited for use[63].

Port of Mtwara is located at the southernmost part of Tanzania close to the Mnazi Bay gas field where natural gas reserves of 5Tcf is expected. Future LNG export terminal is planned in Lindi, north of Mtwara. Mtwara port will play an important role in the early stage of constructing gas industries in receiving materials, heavy cargos and daily commodities for construction workers. Until recently, the port of Mtwara has been used only for export of agricultural crops, however, it is deemed to have a great potential for further development.

In summary, it is important for economic development of Tanzania to expand its freight transport sector, namely, port, road and railway. In considering virtual pipelines, sea port may also play a key role for transporting and receiving natural gas for further transfer to interior domestic markets.

8.3 Options for Virtual Pipeline

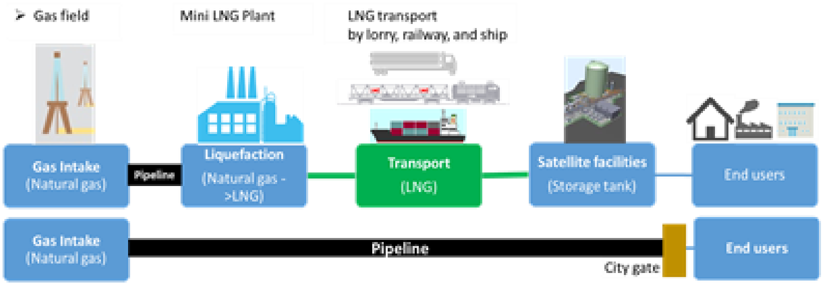
In this section, an overview will be given on the features of technologies and challenges on candidate gas transport systems constituting the Virtual Pipeline. Studies on their respective cost and economic evaluation are conducted in Chapter 10.

8.3.1 Mini-LNG

(1) Overview of Mini-LNG and Gas Delivery Chain

A Mini-LNG delivery chain is one of the options handling natural gas as the virtual pipeline. The Mini-LNG gas delivery chain consists of i) liquefaction of natural gas at the mini-LNG plant, ii) transportation of LNG, iii) re-gasification at the satellite facilities and iv) gas delivery to end-users such as gas-fired power plants, industries, commercial facilities, offices and households. An overview of gas delivery chain is shown in Figure 8.3-1.

[61] African Development Bank (2013) *Tanzania Transport Sector Review*, p. 70.
[62] African Development Bank (2013) *Tanzania Transport Sector Review*, p. 73.
[63] African Development Bank (2013) *Tanzania Transport Sector Review*, p. 79.



Source: JICA Study Team

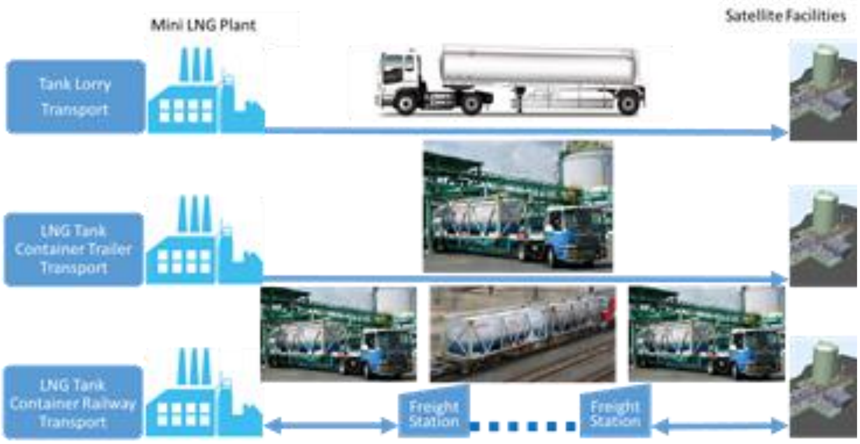
Figure 8.3-1 Overview of Gas Delivery Chain

Compared with pipelines, the mini-LNG is advantageous for transporting small volume of natural gas because of its flexibleness on destination, quantity and distance of gas delivery to the end-users.

The mini-LNG plant liquefies natural gas to be supplied from the gas pipeline already laid in Tanzania or nearby gas field to be developed. The mini-LNG plant consists of a gas pretreatment unit, liquefaction unit, LNG storage tank, loading facility, utility and offsite facilities. The possible options of the liquefaction process are i) single mixed refrigerant (SMR) process and ii) N_2 process. Production capacity of a mini-LNG plant is generally defined to be less than 1MTPA (one million tonnes per annum) and varies according to the scale of gas demand of users.

(2) Methods of Transporting LNG

LNG produced at a mini-LNG plant will be transported by LNG tank lorries, LNG tank container trailers, and/or LNG container railroad cars to satellite facilities where LNG is regasified. A satellite facility will be equipped with storage tanks, vaporizers, calorie control devices and a piping system for LNG storage and control for receiving LNG and delivery of city gas. There are typically three (3) methods of LNG land transport from a mini-LNG plant to satellite facilities as shown in Figure 8.3-2.

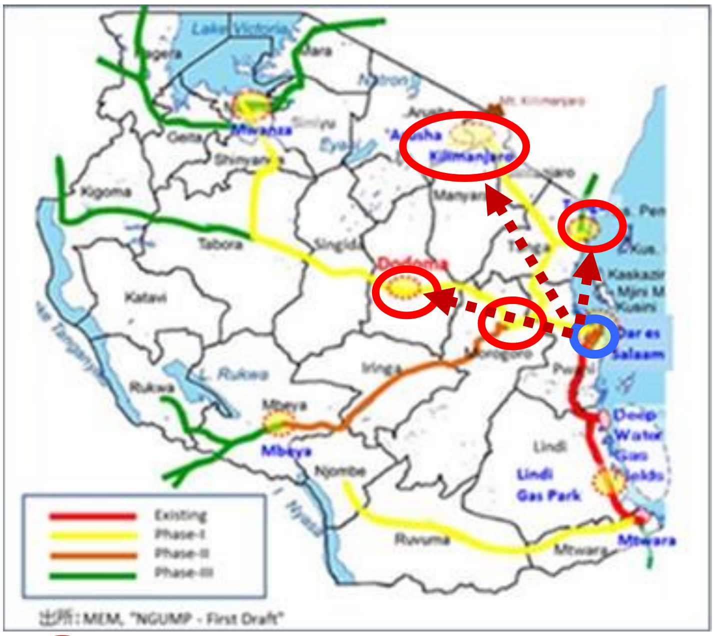


Source: JAPEX and Chiyoda

Figure 8.3-2 Typical LNG Land Transportation Methods

Source: JAPEX

Figure 8.3-3 LNG Tank Lorry and Tank Container



High Energy Demand Areas (Satellite Station)

Trabsportation by LNG containers

Base Station (Mini-LNG Plant)

Figure 8.3-4 Image of Mini-LNG Gas Delivery Chain

Suitable transportation method(s) of LNG in Tanzania should be studied taking account of the size of local gas markets and fuel prices on demand side and expandability, flexibility, CAPEX/OPEX and impact on road traffic and environment on the supply side. A schematic diagram of the gas delivery chain from Mini-LNG plant to end-users is shown in Figure 8.3-4.

In this model, it is assumed that the mini-LNG plant is built in Dar es Salaam where natural gas supply from the existing gas pipeline is available. LNG produced at the mini-LNG plant is delivered to local gas markets, such as Dodoma, Morogoro, Tanga, Arusha and Kilimanjaro, etc., where satellite facilities will be installed for regasification and delivery. When gas demand has grown to a certain level, the gas transmission chain will be replaced with pipeline(s) while the existing chain can be shifted to serve other destinations.

(3) Advantages and Disadvantages

The mini-LNG gas delivery chain has advantages and disadvantages compared with the conventional gas pipeline. Comparison of gas transport by mini-LNG delivery chain vis-a-vis pipeline gas delivery is provided in Table 8.3-1.

Table 8.3-1 Comparison of Mini-LNG Gas Delivery and Pipeline Gas Delivery

	Mini-LNG Gas Delivery	Pipeline Gas Delivery
Flexibility on gas demand changes	♦ Flexible on gas demand increase	♦ Not flexible on gas demand increase
Delivery distance	♦ Flexible on delivery destination/distance changes	♦ Not flexible on delivery destination/distance changes
Supply amount	♦ Suitable for small amount supply	♦ Suitable for large amount supply
Operation and maintenance	♦ Experienced plant operators and maintenance staff are required.	♦ Easy operation and maintenance
	♦ High OPEX.	♦ Low OPEX
Impact to Environment	♦ Impact to environment due to truck's exhaust gas	♦ Impact to environment during construction
Capital efficiency	♦ High efficiency for small amount and short distance delivery	♦·High capital efficiency for large amount and long distance delivery

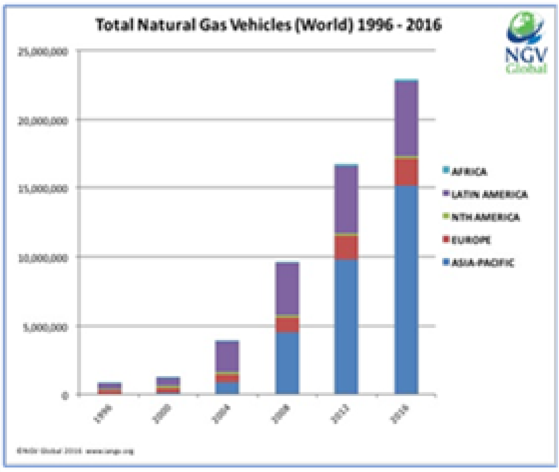
Source: JICA Study Team

8.3.2 CNG

(1) Overview of CNG

Compressed natural gas (CNG) is produced by compression, cooling and dehydration of natural gas and then stored in pressurised tanks. Use of CNG is a mature technology as a transport fuel. Significant trends are observed in the world to promote natural gas vehicles (NGV), especially in gas producing countries. Current status of NGV penetration in the world is:

a) 23 million NGVs in use
b) 30 thousand natural gas fuelling stations in operation



Source: NGV Global

Figure 8.3-5 World Natural Gas Vehicles: 1996-2016

There are mainly two types of NGV fuels, i.e. CNG and LNG, but most of them running in the world are light duty CNG vehicles, while LNG is increasingly used for heavy duty vehicles in China, the U.S., etc.

Major countries with high NGV utilization are shown in Table 8.3-2.

Table 8.3-2 NGV Utilization

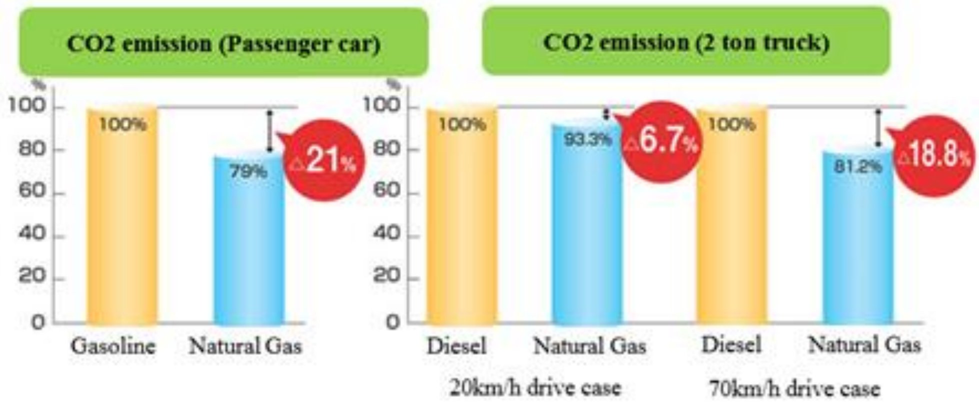
	Country	Natural Gas Vehicles	Refuelling Stations
1	China	5,350,000	8,300
2	Iran	4,502,000	2,400
3	India	3,078,799	1,349
4	Pakistan	3,000,000	3,416
5	Argentina	2,295,000	2,014
6	Brazil	1,781,102	1,805
7	Italy	1,004,982	1,186
8	Colombia	571,668	801
9	Thailand	474,486	502
10	Uzbekistan	450,000	213

Source: ©IANGV 2017. www.ngvglobal.org

The following features of CNG are enjoyed in gas producing countries.

a) Import of oil products can be reduced. Fuel for automotive transportation can be shifted from imported oil products to indigenous natural gas-based fuel.

b) Exhaust gas can be made cleaner. Compared with oil products such as gasoline and diesel oil, combustion of natural gas produces no emissions of SOx and PM (particulate matter), and less emissions of CO_2 and NOx.



Source: Osaka Gas

Figure 8.3-6 Comparison of CO_2 Emissions

(2) Basic Configurations of CNG Delivery System

Delivery of CNG is one of the options for handling natural gas as the virtual pipeline. Operation of CNG delivery system is composed of:

a) Intake of natural gas from the delivery terminal of gas pipeline

b) Compression to 20-25 MPa, cooling, and dehydration

c) Transportation of CNG to CNG satellite stations

d) Decompressing and supplying to users

Transportation of CNG is carried out mostly using large cylinder trailers. Light weight large cylinder modules made from carbon fibre/epoxy with HDPE liner, e.g. Hexagon Lincoln, TITAN composite cylinders, are mostly used.

(3) Advantages and Disadvantages

Utilization of CNG has advantages and disadvantages as listed below:

Advantages:

a) CNG is an economic fuel for transportation, approximately 40 percent cheaper than gasoline.

b) CNG has important feature of higher environmental friendliness, which produces no emissions of SOx and PM (Particulate Matter), and less emissions of CO_2 and NOx, in comparison with oil products;

c) Indigenous natural gas can be utilised for rapidly increasing automotive fuel demand and will reduce import of oil products;

d) As the first phase of CNG introduction, vehicles for public services such as public bus service, garbage collection service and postal delivery service are considered suitable. This is because public service vehicles run within a limited area and therefore can compensate for the disadvantage of CNG vehicles, that is, shorter driving distance per one fuelling in comparison with gasoline and diesel.

Disadvantages:

With regard to gas transportation efficiency in terms of the weight of gas over the total weight of gas and container, CNG is significantly inferior to LNG as shown below.

a) Comparison of transportation efficiency

LNG transport

Container 40 ft. LNG container
Gas weight 18.0 tonnes/container
Tare weight 11.4 ton/container
Total weight 29.4 ton/filled container
Transportation efficiency: 61.2% (Gas weight/Total weight)

CNG transport

Container 40 ft. module composite cylinders (Filament wound carbon fibre/epoxy with HDPE liner composite shell)
Gas amount 7.5 tonnes/container
Empty weight 15.2 tonnes/container
Total weight 22.7 tonnes/filled container
Transportation efficiency: 33.0%

Source: Hexagon Lincoln's TITAN

b) Comparison on frequency of delivery

Transported Gas Amount	One million NM^3
LNG delivery	41 times
CNG delivery	98 times

It is apparent from the above comparison that, in comparison with LNG, gas transportation in the form of CNG is not competitive for longer distance and larger volume transport.

8.3.3 DME

(1) Overview of DME

DME (Di-Methyl Ether) is one of methanol derivatives. It is gaseous at ambient pressure and needs to be liquefied by pressurising to 5 bar or more for transport and storage. The consumption of DME is limited because its use is presently limited to solvent, alternative refrigerant and propellant for spray can, but consumption of DME has recently expanded to fuel use taking advantage of its environmental friendliness; nil or less emissions of SOx, NOx and PM.

Fuel use of DME as blending material with LPG has been developed and commercialised. LPG with DME content of maximum 20% is applied at the existing facilities with little modifications. However, use of DME as fuel for transport and power generation is yet under experimental stage because it needs to be handled under pressurised condition and therefore modification is necessary on storage tanks, fuelling systems and control software.

As for production technology, a two-step process of DME production is commercialised, i.e. methanol production from natural gas in the first step and then DME production from methanol in the second step. In the NGUMP study for Tanzania, methanol and DME production was studied assuming its candidate plant location at Lindi.

(2) Basic Configuration of DME transportation

A DME plant may be located at Lindi as studied in the NGUMP study. Then DME will be transported to Dar es Salaam, where DME is blended with imported LPG. DME needs to be liquefied by pressuring it to 5 bar or more. While the existing transportation infrastructure of liquid petroleum fuel is operated under ambient pressure, it needs to be modified to pressure resistance requirement for handling of DME. On the other hand, LPG transportation infrastructure can handle pressurised liquids. LPG blended with DME is delivered by the existing LPG delivery chain using the existing LPG infrastructure.

LPG blended with DME can be used by existing equipment at residential and commercial users. Especially, delivery by existing LPG container is suitable for the use by isolated small users such as residential and commercial users in remote areas.

(3) Advantages and Disadvantages

Utilization of DME has advantages and disadvantages as below:

Advantages

a) LPG blended with DME can replace the fuel at residential and commercial users from biomass fuels (charcoal, firewood, etc.), which are currently used as major fuel. This could help prevent forest deterioration and improve living standard.

b) LPG consumption, which is imported, can be replaced by gas product from indigenous resources.

c) Existing LPG infrastructures can be utilised.

Disadvantages

a) Production of DME is influenced by methanol production, which is mainly export-oriented.

b) A new transportation system becomes necessary to connect the DME production site to the LPG blending site. (However, transport of DME can be carried out by using LPG infrastructures without any technical problems.)

8.3.4 GTL/LPG

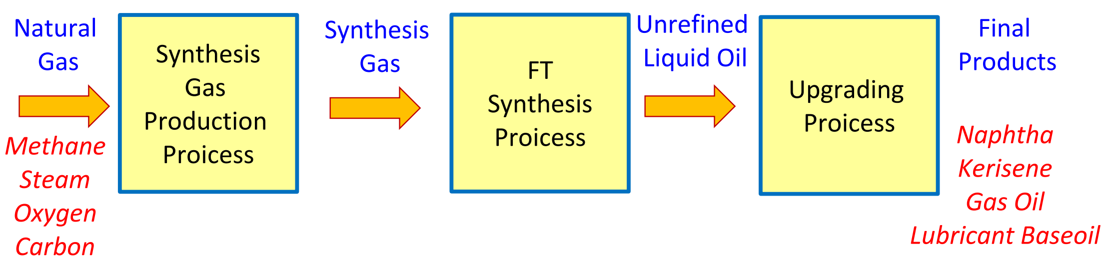
Gas to Liquid (GTL) is a technology to convert natural gas into liquid petroleum products. The technology enables manufacturing liquid hydrocarbon, such as naphtha, kerosene, and gas oil, from natural gas. LPG is also produced as a part of the products. Compared with gaseous products, GTL products are liquid under normal temperature and pressure, and thus easier to handle.

GTL is produced in the following three steps:

1) Production of synthesis gas (mixed gas of hydrogen and carbon monoxide) from natural gas;

2) Conversion of the synthesis gas to crude liquid fuel by FT (Fischer Tropsch) reaction;

3) Refining of crude products into final products (naphtha, kerosene, gas oil, lubricant base oil, etc.) by upgrading processes.



Source: JICA Study Team

Figure 8.3-7 GTL Process Steps to Produce Products

Leading companies of GTL technologies are Sasol of South Africa and Shell, an international oil major. Sasol started GTL production of 34,000 BPD in Qatar in 2007 (Oryx GTL) in addition to their plant at Secunda, South Africa. Shell began operation of the GTL plant of 14,700 BPD called Shell Middle Distillate Synthesis (SMDS) in Malaysia in 1993. In the Qatari “Pearl GTL” project, Shell started operation of a GTL plant in 2011 which is significantly ramped up to 70,000 BPD and the second train (70,000 BPD) in 2012.

GTL business is regarded as a “gap business” that targets certain price gap between low feed gas price and high petroleum product prices. Since the raw material is natural gas and the outputs are petroleum products, the difference between these prices are important to keep the GTL business healthy. The larger the difference between the gas price and the petroleum product prices, the better the economics of the GTL business. In its every aspect, GTL is a highly challenging business that engages sophisticated technology and complex process and requires financial resilience to tolerate a great deal of market uncertainties.

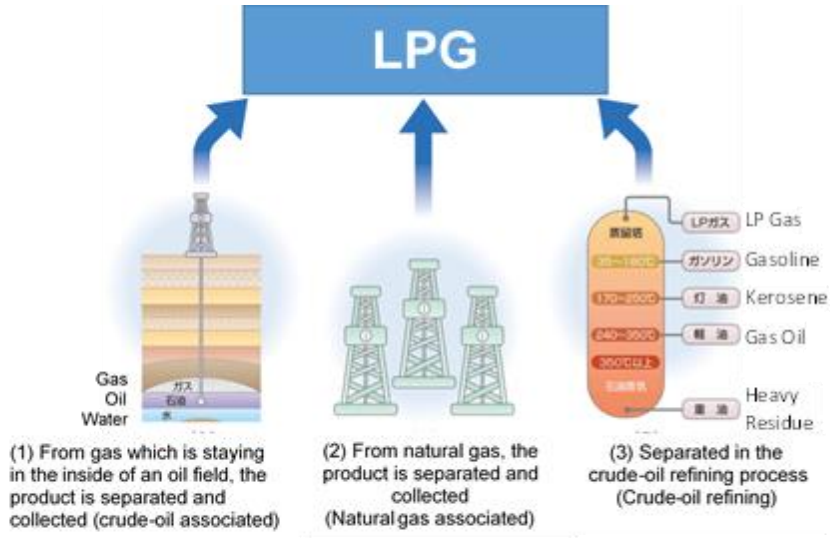
GTL has been developed in countries like Qatar where gas resources are abundant and GTL is considered as one of the options of gas-resources development in addition to a pipeline or LNG or, like South Africa, where oil resources are scarce and oil import was banned by international moratorium against its Apartheid policy. For a country without oil production and importing crude oil and petroleum products, GTL may be considered as an option to diversify liquid fuel supply sources using natural gas. It will also reduce foreign currency payment replacing import of petroleum products.

On the other hand, the present GTL process has an unavoidable weak point in its energy efficiency. In the first stage of the process to produce synthesis gas ($CO+H_2$), the feed gas is half burnt (oxidised) incurring significant loss in heat value. The overall conversion rate at the latest commercial plant is about 50% against the heat input, while the absolute technical limit is 72%. In addition, at least several billion dollars will be required as the initial investment cost. With this huge upfront expenditure, GTL has to be exposed to fluctuation of the price gap between feed gas and petroleum products. As such, decision making on a GTL project tends to be very difficult.

Propane and butane as sources of LPG exist together with other hydrocarbons in underground oil and gas fields. They are produced from natural gas, associated gas and crude oil. At gas processing plant at gas field and LNG plant, gas hydrocarbons are separated into methane, ethane, propane, butane, and heavier components. LPG is produced after removing impurities such as sulfur and mercury, and pressurising propane and butane into liquid form. Some gases remain in crude oil after stabilisation process. Propane and butane dissolved in crude oil are separated in oil refining process, and recovered for production of LPG.

Traditionally, Saudi Arabia has supplied huge amounts of LPG recovered from the associate gas of its crude oil production, and hence has exerted a strong control on the world LPG markets. Afterwards, development of LNG production has brought substantial amounts of LPG in the past two decades pushing it to an influential power. The latest development is a rapid increase of LPG production in the United States associated with tight oil production as discussed in Chapter 2.

The main component of LPG is propane and it is delivered mostly in cylinders (canisters or bombs) except for large bulk users. LPG is used at home as fuel for cooking stoves, space heating stoves, water heaters, etc. In recent years, a highly efficient fuel cell system that co-produces electricity and heat using LPG is spreading widely in Japan. At industrial and commercial sectors, which are isolated from the piped city gas system, LPG is transported by tank trucks and used as heat source for their equipment. It is used for heating burners at civil engineering works, for portable combustion equipment (portable gas stove, generator, lighter gas, etc.), for air conditioner and hot water supply, for co-generation system, and also as the fuel for LPG automobiles.



Source: JICA Study Team

Figure 8.3-8 LPG Production Method

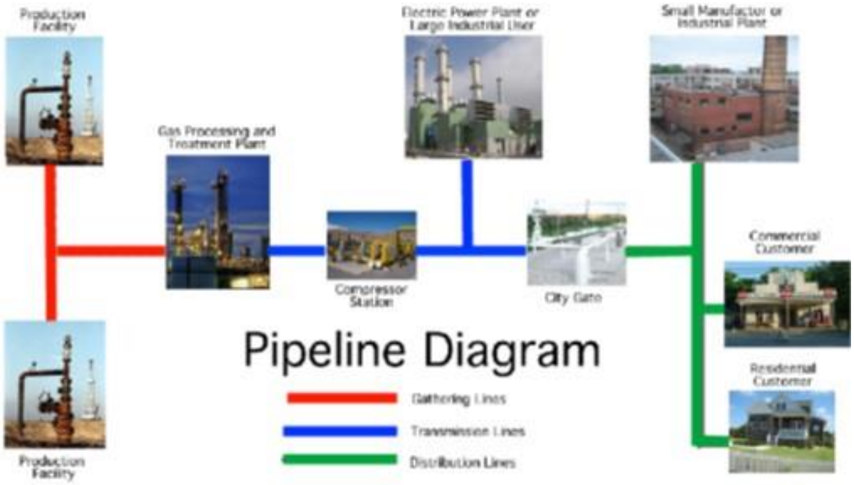
LPG can be delivered in small quantities and for long distance without special infrastructure; it is suitable for supplying energy to scarcely populated areas. In Japan, LPG played an important role of restoring communities quickly from devastating disasters such as earthquake and tsunami.

8.3.5 Gas Transport Pipeline

Pipelines are generally used to transport a large amount of natural gas safely and stably. A pipeline transportation system consists of major components as described below:

a) Steel pipes welded or coupled together for required length;
b) Pig stations for inspection and cleaning;
c) Cleaning and safety devices such as emergency shut-off valves and safety valves;
d) Metering stations for natural gas transaction;
e) Pressure control systems;
f) Control centre to monitor, record and control the flow and pressure of the gas in the transportation system, as well as to detect leak or rupture.

At the gas field, gases are sent from the wellhead to the gathering station by in-field pipe system, and further to the gas processing plant. The refined gas will be sent via pipeline to city gas companies or directly to large scale users such as power plants or industrial users. Transmission pipelines use relatively high pressure (1.0-10.0MPa) and large diameter pipes (6”-48”). The pipeline pressure is controlled at compressor stations taking account of the wellhead pressure and transportation distance. Gas may be compressed if necessary. In the demand centre, after pressure control, natural gas is distributed to end users via low-pressure distribution lines to general households or small factories at a comparatively low pressure (0.1-1.0MPa).

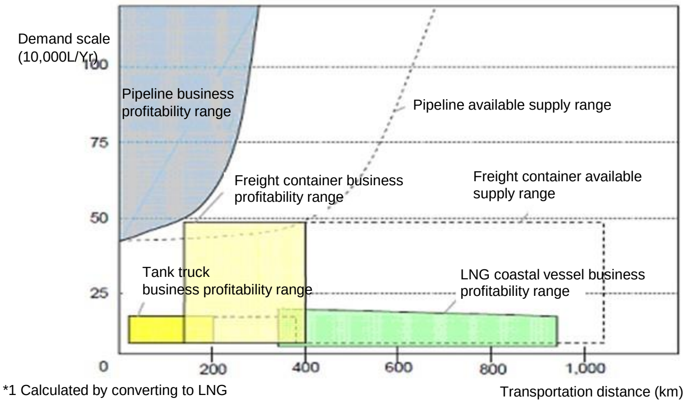


Source: Pipeline Safety Trust-Pipeline Briefing Paper #2, Sep. 2015

Figure 8.3-9 Pipeline Diagram

Among infrastructure systems for natural gas supply, the pipeline system is considered more effective for a large-scale gas transport with less impact on the environment and a higher degree of safety and security. When a pipeline system is expanded to cover wide areas, supply reliability for the whole market improves; the end pressure of a pipeline network becomes more stable with multiple pipeline linkage and mutual backup in case of emergency, which altogether contributes to improving security. On the other hand, since the upfront investment amount is relatively large and demand build-up period is longer before reaching the full capacity operation, it is necessary to carefully investigate economics of gas transport by pipeline.

Among safety requirements during the pipeline operation, corrosion protection is very important. Unprotected steel pipelines are susceptible to corrosion in particular when impurities such as CO_2 and H_2S are contained. Without proper corrosion protection steel pipes will easily deteriorate making pipelines unsafe for use. Most of accidents such as gas leakage from gas transportation pipelines and/or gas explosion are caused by corrosion of pipelines, save for accidents caused by the external influence such as other construction work or terrorism and vandalism.



Source: Investigation report on the development of short-range maritime transport system of natural gas (The Ocean Policy Research Institute, 2009)

Figure 8.3-10 Profitability Ranges of Natural Gas Transportation Methods

Today, technologies are well developed to control corrosions and enable extension of pipeline life. Typically, there are three methods to protect pipelines from corrosion: coating of pipelines, cathodic protection of pipeline and injection of corrosion inhibitors during operation. In addition, because refined natural gas has no odour, a mercaptan odorant is injected into city gas so that a gas leak can easily be detected by the unpleasant odour. Generally, periodic inspection patrol of pipeline is obligated under laws and regulations for safety and detection of gas leakage.

8.3.6 LPG import

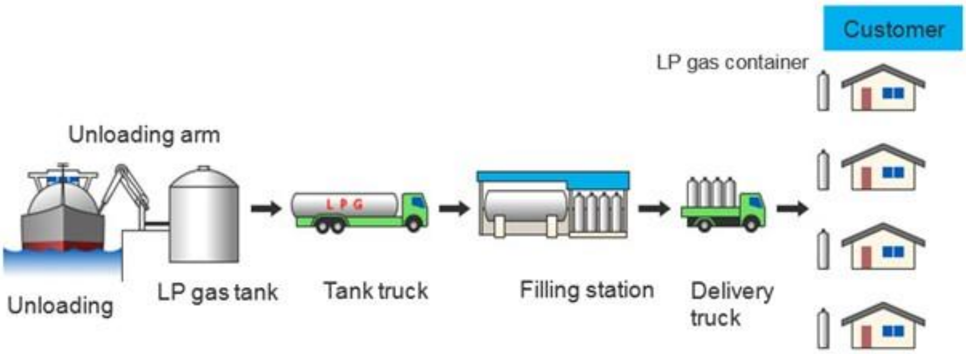
Tanzanian indigenous natural gas is extremely light and contains only a very small amount of propane and butane that could be used as the feedstock for LPG. Therefore, to disseminate LPG nationwide, LPG should be imported from abroad. As sources for the LPG import, major LPG production countries are listed in Table 8.3-3.

Table 8.3-3 LPG: Production and Exports

Rank	Production			Export		
	Country	Quantity	Year	Country	Quantity	Year
		kt			kt	
1	United States	61,071	2016	United States	27,719	2016
2	China	29,344	2015	Saudi Arabia	20,293	2015
3	Saudi Arabia	28,220	2015	Qatar	9,152	2015
4	Russia	18,622	2015	United Arab Emirates	7,361	2015
5	India	11,057	2015	Algeria	7,310	2016
6	Qatar	10,125	2015	Norway	5,743	2016
7	Algeria	9,358	2016	Kuwait	4,791	2015
8	United Arab Emirates	8,789	2015	Russia	3,687	2015
9	Norway	6,475	2016	Iran	2,639	2015
10	Thailand	5,513	2015	Kazakhstan	1,997	2015
11	Brazil	5,477	2015	Netherlands	1,971	2016
12	Iran	5,051	2015	China	1,442	2015

Source: UN Data

Presently, the United States is the largest LPG producing country in the world. For mass transportation of LPG, specialised LPG vessels or tank trucks are required. Considering the location of Tanzania, import from Saudi Arabia, Qatar and UAE is considered realistic. Imported LPG is carried from a primary base to a secondary base by coastal vessels, railways or tank trucks. Then, LPG is bottled in cylinder containers at filling stations and delivered by trucks to small lot consumers and households.



Source: Home page of the Japan Gas Association

Figure 8.3-11 LPG: Import through Delivery to Home

The final delivery method is different between city gas and LPG; city gas is supplied through gas pipelines, while LPG is delivered in cylinders.

LPG tank truck

LPG cylinder

Figure 8.3-12 LPG Delivery

LPG is supplied to customers as fuel for gas stoves, water heaters and portable gas stoves, and LPG automobiles.

Household gas stove

Portable gas stove

LPG automobile

Source: Japan LP Gas association

Figure 8.3-13 Use of LPG

8.4 Technical Challenges

(1) Pipeline

Pipeline is mainly and widely used for natural gas transportation. Natural gas pipelines are developed worldwide in view of its advantageous characteristics as transportation infrastructure with excellent economics and stability in operation. Once a pipeline is built, no complex operation is required; it will be operated stably and its energy efficiency is better than other transportation methods if high utilization rate is achieved. In terms of reliability and security, since pipeline is usually buried underground, there would be little influence of weather or fewer accidents caused by external factors.

On the other hand, pipeline capacity is relatively inflexible. At starting, it may need to wait for demand build-up for certain period and, if demand expands at a later date beyond its capacity, additional pipeline needs to be laid down to accommodate the incremental demand. Therefore, it is important to design the future expansion plan very carefully in order to realise optimum long-term utilisation. Another controversial issue for construction of pipeline is securing right of way. If it needs to cross international border(s), this issue would become more complex and difficult, and sometimes develop into geopolitical disputes.

(2) Virtual Pipeline

No technical issue is anticipated on the Virtual Pipeline concept since all of Mini LNG, CNG, DME, GTL and LPG, conceived as a natural gas transportation alternative to pipeline, use matured technologies with proven track records. Virtual Pipeline is advantageous as it enables multipoint distribution. In other words, Virtual Pipeline can distribute natural gas not only to single demand point, but also to multiple demand points with flexibilities in supply volume corresponding to increasing demands. Especially in Tanzania where demand areas or points are scattered all over inland, the virtual pipeline system and its stepwise development will be deemed as a reasonable solution considering difficulties in accurately predicting the future demand size and development path. However, in adopting the virtual pipeline, natural gas should be changed in its physical form at the gas production site for transport to demand sites by trucks, rails or ships, and finally returned into the gas form, causing certain amount of energy to be required in these processes. At any rate, the cost of transport would be expensive when demand size is small. Optimum method must be sought by examining various options, accordingly.

(3) City Gas Supply System

In order to supply city gas, it is necessary to develop a low-to-medium pressure delivery network, where the gas supplier who intends to construct such a network for small demand must carefully examine the cost effectiveness involved. This is because the cost of transporting gas is determined by the cost effectiveness which greatly affects the final gas cost at the demand point.

From the safety point of view, methane is safer than LPG as it is lighter than air. It does not stay low in the air even when gas leaks, though mistakes in handling would still cause dangerous accidents. In order to use gas safely at the point of demand, it is important to implement i) periodic inspection of gas piping and consuming equipment, ii) dissemination of information for customers on how to respond in case of emergency, and iii) training for quick response in case of emergency. For this purpose, gas suppliers must establish a security system and develop requisite human resources.

City gas supply is in principle based on proved technologies and therefore no serious problems are anticipated on hardware. As mentioned above, however, an optimum method should be carefully sought out with regard to demand size, applicable technologies and their costs.

Chapter 9 Virtual Pipeline versus Real Pipeline

In this chapter, comparative economics is analysed on LNG, CNG and real pipeline as a vehicle for small scale gas transport. Based on the analysis in Chapter 7, the following two cases are assumed as the plant size for the analysis.

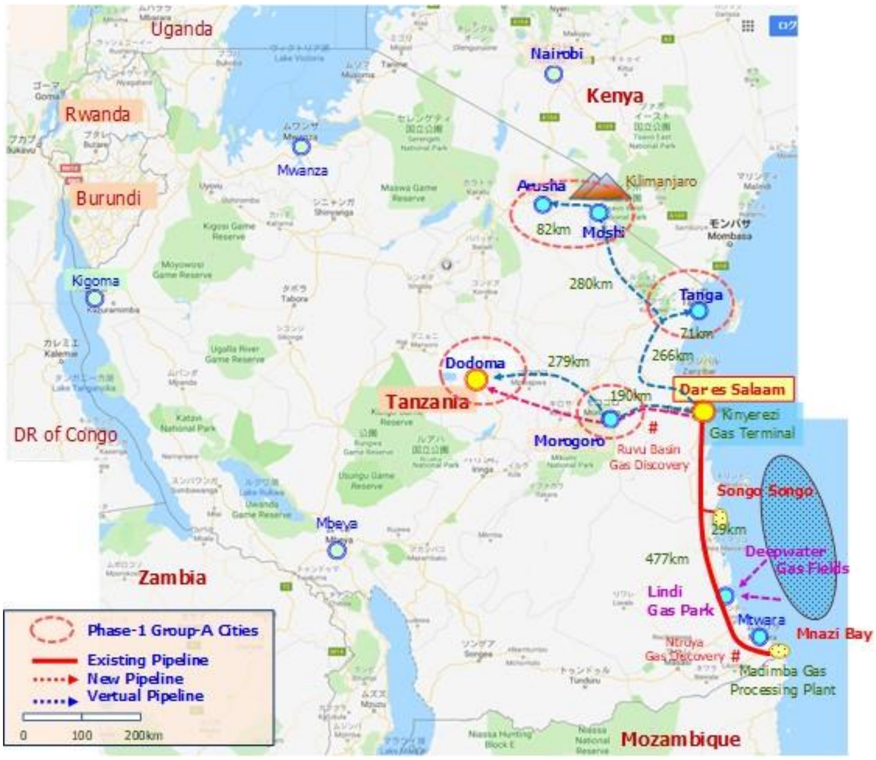
Case-A: 200 tons/day in LNG equivalent (100 tons/day plant x 2 trains)

Case-B: 400 tons per day in LNG equivalent (200 tons/day plant x 2 trains)

Natural gas will be sold to the city gas system in Dodoma, large industry users located anywhere in the object area directly delivered by bulk transport, at gas service stations as automotive fuel, and as an optional case, the Zuzu power station.

9.1 Options for Gas Supply Method and Business Flow

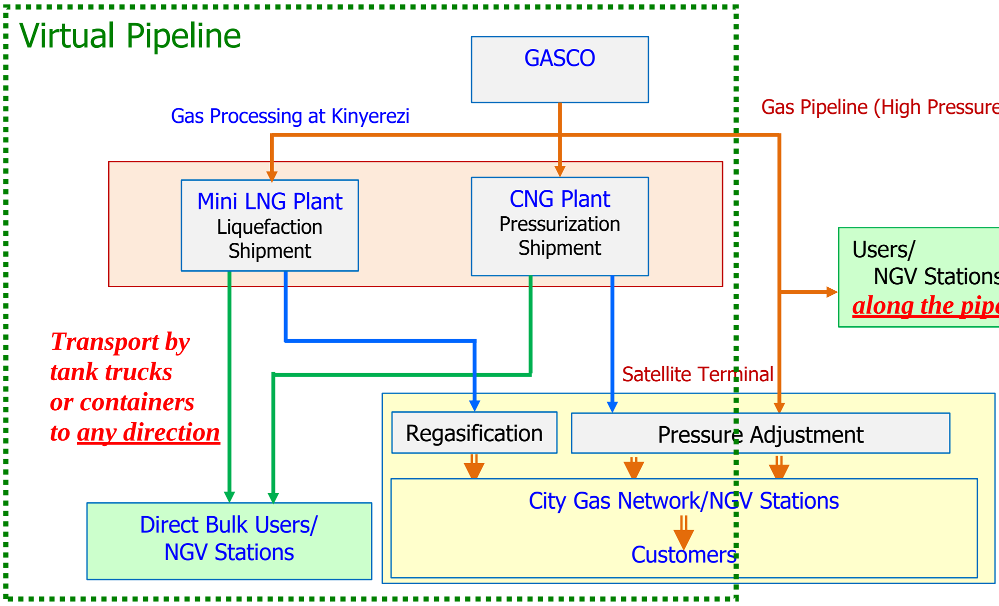
In this analysis, we assume that the feedgas for the new gas supply system will be obtained from the existing GASCO system at the Kinyerezi gas terminal. Natural gas is supplied there from the Songo Songo and Mnazi Bay gas fields; it is "processed gas" of quality for commercial delivery. The trunk gas pipeline connected to the terminal has a capacity of transporting 784MMcfd, which can be increased to 1,002 MMcfd by boosting-up. Late 2018, it was being run at 80-90MMcfd or at around 10% of the capacity. Sufficient surplus capacity is available for new outlets.



Source: JICA Study Team

Figure 9.1-1 Gas Supply for Virtual Pipeline

In case of a virtual pipeline, namely LNG or CNG, gas will be processed at Kinyerezi for transport to Dodoma city gas satellites, bulk users and Gas service stations by trucks using containers. LNG or CNG will be delivered to any direction as far as it is commercially viable. In case of a real pipeline, it simply branches at the Kinyerezi terminal to Dodoma picking up only major users along the pipeline route. Upon arrival at Dodoma, gas will be conditioned to medium pressure at satellite terminals before distributed as city gas. Figure 9.1-2 shows the schematic gas flow from the Kinyerezi Gas Terminal to destinations.



Source: JICA Study Team

Figure 9.1-2 Options of Gas Flow from Kinyerezi to Dodoma and Other Destinations

9.2 Outline of Gas Transport System and Costs for Construction and Operation

The natural gas transport system from the Kinyerezi Gas Terminal to its destinations comprises a processing plant for LNG or CNG plus truck transport, or pipeline, and satellite terminals to receive and condition natural gas for city gas supply or direct use. Here, Case-A corresponds to a gas supply amount of 100 tons per day in LNG equivalent times 2 trains and gas sale to the city gas system at the New Government City in Dodoma, direct bulk users, and four Gas service stations one located at the NGC and three elsewhere en route from Kinyerezi to Dodoma. Case-B corresponds to gas supply of 200 tons per day in LNG equivalent times 2 trains and gas sale to all destinations, namely, city gas at NGC, Dodoma Central Business District (CBD), Iyumbu Satellite Centre, Zuzu power station, all direct bulk users and five Gas service stations one each at the NGC and Zuzu and three en route to Dodoma. Outlines of these facilities and their estimated costs for construction/operation are estimated as below.

9.2.1 Gas Supply Facility at Kinyerezi

1) Pipeline

In case a real pipeline is laid down from Kinyerezi to Dodoma, simply natural gas is received at the Kinyerezi Gas Terminal and transferred to the new spur. Presently, natural gas is received at Kinyerezi at 90 bars and delivered to the Ubungo power plant and gas delivery station at 75 bars, to the Kinyerezi-1 power plant at 35 bars and the Kinyerezi-2 power plant at 55 bars. The new pipeline may be designed with the inlet gas pressure at Kinyerezi at 70 bars and the arrival pressure at the destination at 60 bars. A lower arriving pressure is acceptable; thus, no compression is necessary at Kinyerezi.

The pipelines will be with a diameter of 12" or 20", and their transport capacities will be:

a. 12" pipeline: 14,000m^3per hour or 4.4 Bcf per year
b. 20" pipeline: 50,000m^3 per hour or 15.6 Bcf per year

The steel pipeline with design pressure capacity of 75 bars will be laid down for 500km attached with pig stations for maintenance and cleaning, safety systems with emergency block valves and relief valves, metering stations for identification of transaction amount, pressure control systems, a control centre to monitor, control and record the gas flow and pressure, etc. In between Kinyerezi and Dodoma, gas may also be supplied to users along the pipeline route branching from any valve point.

2) Mini-LNG

The LNG plant will be built next to the existing Kinyerezi Gas Terminal and the feedgas will be obtained from there. The main facilities comprise gas piping to receive the feedgas, pre-treatment facilities (for removal of acid gas, dehydration and de-mercury), natural gas liquefaction unit, LNG storage and LNG loading/shipping facilities. Their outlines are as follows:

Case-A: production capacity at 100 tons per day (9.7MMcfd) x 2 trains

a. Main Facilities
    - Gas engine generator
    - Cryogenic heat exchanger made of aluminium
    - Refrigerant compressor and its driver
    - Air separator (to produce N_2 as refrigerant)
b. Storage: Bullet type LNG tank (600kL) x 2
c. LNG loading/shipping facility

Case-B: production capacity 200 tons per day (19.3 MMcfd) x 2 trains

a. Main Facilities
    - Gas engine generator
    - Cryogenic heat exchanger made of aluminium
    - Refrigerant compressor and its driver

- Air separator (to produce N_2 as refrigerant)

b. Storage: Bullet type LNG tank (600kL) x 3

c. LNG loading/shipping facility

Since 6 units of gas turbine generators are in operation at Kinyerezi, it is conceivable to use electricity driven gas compressor. This would eliminate the gas engine generator listed above.

3) CNG

Similarly with LNG, a CNG plant will be built next to the Kinyerezi Gas Terminal. Main facilities will be piping to receive the feedgas, pre-treatment system for dehydration, gas compressors, gas cooling system and gas loading/shipping bays. As the compressed gas is directly loaded into CNG containers, such plant has no tank for CNG storage. However, certain number of containers should be kept at hand as working inventory for smooth operation.

4) Summary

Construction costs of the above pipelines, and LNG and CNG plants are estimated as shown in Table 9.2-1.

Table 9.2-1 Construction Cost for LNG/CNG Plants and Pipeline

Options	Mini LNG		CNG		Pipeline	
Case	A	B	A	B	φ12"	φ20"
Capacity (tons per day LNG equivalent)	200	400	200	400	270	980
	$ million	$ million	$ million	$ million	$ million	$ million
Estimation (w/o storage containers for CNG)	88.3	137.4	19.3	31.1	524.4	555.0
Round up (Adopted)	90	140	20	32	525	555

If the gas demand grows beyond the supply capacity scheduled above, new trains may be added. If a greater demand is expected, higher capacity plants may be built. Such being the case, an LNG plant may enjoy certain scale-merit of plant ramp-up, while a CNG plant will merely pick up more compressors without any scale-merit.

9.2.2 Gas Transport by Container Trailers

Natural gas in the form of LNG or CNG may be transported by tank-truck, or trailers or trains with containers. The new standard gauge railway is now under construction linking Dar es Salaam and Dodoma to be completed shortly. Railway transport using this line will be a future promising option. In this study, we assume use of container trailer-trucks and that necessary vehicles will be procured stepwise as demand grows. Carrying capacity of a container is significantly different between LNG as liquid and CNG as gas, and hence the number of containers required will be considerably large for CNG for Case-B.

The most modern versions of vehicles are adopted here. Major cost elements are estimated as follows:

a. The capacity of a container is 18 tons for LNG and 7.5 tons for CNG compressed to 250 kg/cm^2.
b. Costs of new vehicles are estimated to be $100,000 per unit for a trailer head and $200,000 per unit of container and chassis combined. In addition to the CIF cost of the vehicles, there will be 50% additional fees including import duty, excise tax, handling fee, etc.[64]
c. Usable life will be 10 years for a trailer and 20 years for a container unit.
d. Fuel mileage will be 2 km per litre of diesel gas oil.

The driving distances from Dar es Salaam are 190km to Morogoro and 470km to Dodoma, plus 10km or so for inner city drive. It may take two (2) days for a round trip to Dodoma and one (1) day to Morogoro. Considering the time for loading and unloading, 30-60 minutes, such operation may be conducted by site operators. Thus, we assume that one unit of vehicle makes 12-16 round trips a month operating 24 days per month which corresponds to 80% utilization. Then, the number of vehicles required is estimated as shown in Table 9.2-2.

Table 9.2-2 Vehicles Required for Gas Transport

	Case-A			Case-B		
	2025	2030	Max	2025	2030	Max
Vehicles Required			(2051)			(2033)
LNG	5	8	20	21	42	44
CNG	12	18	46	50	99	105
Drivers Required						
LNG	11	17	42	44	88	92
CNG	25	38	97	105	208	221
Cumulative Investment	$k	$k	$k	$k	$k	$k
LNG	2,700	3,600	13,950	11,700	19,350	45,300
CNG	5,850	8,100	33,000	27,450	45,900	107,550

Source: JICA Study Team

Two drivers are assigned to a trailer truck with 5% back-up workforce as allowance for leave. Compared with LNG transport, 2.4 times of vehicles and drivers are necessary to transport CNG which reflects the difference of the gas load on one container. As the number of vehicles and drivers increases greatly when demand grows, the transport sector may be out-sourced to transport service providers in order to streamline the gas company management.

The cumulative investment amount is calculated applying the unit cost as explained above. In case of CNG, the vehicle cost is much greater than the CNG plant cost (see Table 9.2-1 and 9.2-2).

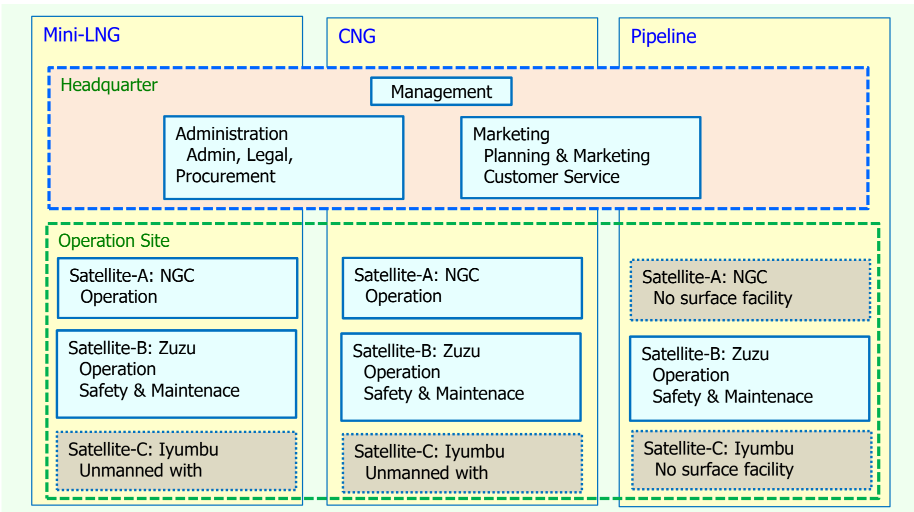
[64] For a new vehicle with engine size over 2,500CC, following fees are levied: import duty 25.0%, VAT 18.0%, Custom Processing Fee 0.6%, and Railway Development Levy 1.5%. For used vehicles, "Excise Duty due to Age" will be levied 15% for vehicles older than 8 years and 30% older than 10 years. Cars with smaller engine size are subject to another 5% Excise Duty.

9.2.3 Organisation for Operations

1) Gas Processing and Transport

A model organisation chart for the gas processing and transport sector is shown below. In case of LNG and CNG, there will be an integrated gas supply company with certain number of workforces that cover marketing, gas processing and gas transport activities. An LNG plant may be operated 24 hours with three shifts a day. On the other hand, a CNG plant will be operated with one shift a day since the necessary gas treatment is just to compress the gas up to 250 bars. In both cases, the marketing team should take care of the existing customers as well as promotion of market development. Truck operation may be out-sourced from contractors while thorough training on operation and safety is necessary.

In case of a real pipeline, however, the branch line may be controlled by the existing operating team and monitored by the existing maintenance team of GASCO with some additional staff. Marketing activities may be minimal as the number of users is limited to those whom the pipeline is connected.



Source: JICA Study Team

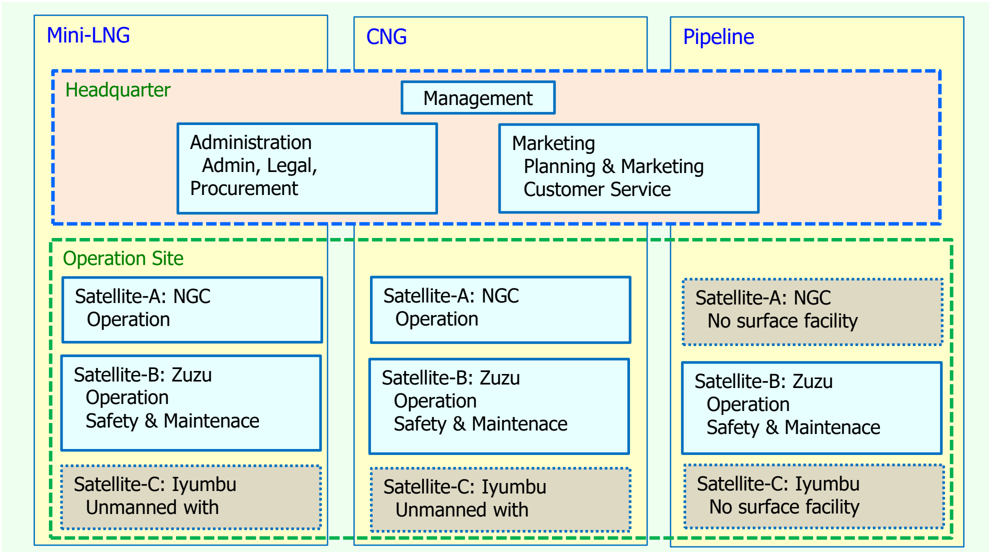
Figure 9.2-1 Organisation on the Gas Supply Side

2) City Gas Supply

At the other end of the gas transport system, there should be a satellite terminal to receive gas and city gas distribution network. Generally gas receiving terminals are operated as a part of a city gas company's function. Third party access may be considered once the natural gas network has reached certain mature stage in the future.

The city gas company may have its own management centre for administration/marketing and an operation centre attached to the satellite terminal where gas is received and dispatched to customers. In addition to a routine operation team, there should be a customer service team standing-by around the clock for emergency response.

Operation system for LNG and CNG are similar except for vaporizers necessary for LNG. In Case-B, the Satellite-B will be the operation centre which also look after operation of other satellite terminals. Satellite-C will be operated without any permanent staff; operators will attend when a cargo is unloaded. In case that gas is received via pipeline, no surface facility will be necessary for Satellite-A and C.



Source: JICA Study Team

Figure 9.2-2 Organisation of City Gas Company

9.2.4 Satellite Terminal

At the other end of the gas transport system, there will be the satellite terminals A, B and C to receive natural gas from Kinyerezi and distribute it as city gas. As the city gas distribution system is common among transport options under consideration, we analyse here the differences in satellite facilities to receive, store and retrieve the gas before inputting it to the city gas network. City gas system itself will be discussed more in detail in the next chapter.

Source: Tokyo Gas, Ishii Iron works, Heritage Gas

Figure 9.2-3 Gas Storage System: LNG vs CNG

City gas users of the new system must be assured of stable supply. In considering gas supply via virtual pipeline, we need to take note that the gas is brought by surface transport, trucks, railway and/or ships, between the supply point and the satellite terminals. They are subject to risks of interruption caused by bad weather, accident, etc., while a real pipeline is least affected by such events. To assure stable supply of gas via the virtual pipeline, certain amount of stock needs to be kept at a satellite terminal, for example a week. Then, the following points need to be examined;

a. LNG may be kept at a satellite terminal as liquid, which is compressed to 1/600 of the gaseous volume. Storage tank may be relatively compact.

b. CNG can be held at a very high pressure, 250 kg/cm^2 (compression to 1/250), only in a narrow tube container. If a large gas tank is used, it can hold gas only at much lower pressure, 10 kg/cm^2 (compression to 1/10) or less because of its structural strength[65].

Table 9.2-3 shows the necessary storage capacity at each satellite to hold 7 days stock with an average stock level at 70%. For Satellite-A it will be 143 tons or 333 KL in LNG equivalent for 2025 and 314 tons or 736 KL for 2030, for Satellite-B 171tons or 401 KL for 2025 and 371 tons or 868 KL for 2030 and for Satellite-C 11 tons or 26 KL for 2025 and 29 tons or 69 Kl for 2030. In case natural gas is supplied to the Zuzu power station, the required tank capacity at Satellite-B will be 1,178 tons or 3,000 KL for 2025 and 2,513 tons or 6,000 Kl for 2030.

Table 9.2-3 Required Stock for 7-days Shipping

	Demand in LNG Equivalent						Required Capacity (LNG)	
	Annual		350 days/year		7 days		Storage at	70%
Satellite	2025	2030	2025	2030	2025	2030	2025	2030
City Gas + NGV SS	t	t	t	t	t	t	t	t
A	5,000	11,000	14.3	31.4	100	220	159	349
B	6,000	13,000	17.1	37.1	120	260	190	413
C	400	1,000	1.1	2.9	8	20	13	32
Total	11,400	25,000	32.6	71.4	228	500	362	794
B with PS	37,200	76,000	106.3	217.1	744	1,520	1,181	2,413
	7 days storage capacity as LNG				7 days storage capacity as CNG			
	Tank (KL)		Container (units)		Tank (KL)		Container (units)	
	2025	2030	2025	2030	2025	2030	2025	2030
City Gas + NGV SS								
A	380	820	9	18	20,000	44,000	20	42
B	450	970	10	21	24,000	52,000	23	50
C	30	80	1	2	2,000	4,000	2	4
Total	860	1,870	20	41	46,000	100,000	45	96
B with PS	3,000	6,000	60	122	149,000	304,000	142	290

Natural Gas Specification
LNG Specific Gravity 0.427
Gas/liquid Volume Factor 592
Ullage 10% LNG tank only

CNG Pressures
Containers 250 kg/cm2
Gas Tank 10 kg/cm2

Containers Capacity
LNG 18.0 tons
CNG 7.5 tons

Source: JICA Study Team

From the above calculation of the required 7 day-stock for 2030, a typical storage tank capacity in terms of LNG may be assumed as 450KL x 2 for Satellite-A, 500KL x 2 for Satellite-B without the Zuzu power station or 23,000KL x 2 for Satellite-B with gas supply for the Zuzu power station

[65] At Tokyo Gas Company, large gas holders are operated with a pressure range of 0.2-0.7 MPa.

and 80KL x 1 for Satellite-C. Then, if they are to be held in CNG containers (250/kg/cm^2, 7.5ton) or standard type medium pressure gas tanks (design pressure at 10kg/cm^2, 4,000kl with ϕ =10m), 42 containers for Satellite-A, 290 containers for Satellite-B with Zuzu power station and 4 containers for Satellite-C are necessary, or 11 units of gas tanks for Satellite-A, 79 units for Satellite-B and 1 unit for Satellite-C. These big numbers are unrealistic and inconceivable. But, for simplicity of comparison, the CNG satellite cost is calculated considering the great number of CNG containers required to hold 7 day stock.

Table 9.2-4 Storage Capacity for 7 Days Stock

Location	LNG Tanks (KL)					CNG Containers (Units)		4000kl Gas Tanks (units)	
	Size	2025	2030	2025	2030	2025	2030	2025	2030
	KL			KL	KL				
A	450	1	2	450	900	20	42	5	11
B	500	1	2	500	1,000	23	50	6	13
C	80	1	1	80	80	2	4	1	1
Total		3	5	1,030	1,980	45	96	12	25
B with PS	2,000	2	3	4,000	6,000	142	290	37	76
Case-B Total	2,530	4	6	4,530	6,980	164	336	43	88

Source: JICA Study Team

In summary, the following facilities will be built at satellite terminals.

a. LNG: Truck yard +Bay for unloading+ LNG tank + Vaporizer + Control system

b. CNG: Truck yard +Bay for unloading + CNG Container +Control system

c. PNG: Control system only

In case of LNG, stock tanks and vaporizers will be installed as follows:

a. Satellite-A: 450kl tank x 2 + 1 t/h vaporizer x 5

b. Satellite-B: 2,000kl tank x 3 + 10t/h vaporizer x 4

c. Satellite-C: 80kl tank x 1 + 0.3 t/h vaporizer x2

In case of CNG, corresponding numbers of CNG containers (42 for Satellite-A, 290 for Satellite-B and 4 for Satellite-C) to keep 7days stock are hypothetically counted only for cost comparison purpose.

（Table 9.2-5 is withheld because of confidential information）

9.2.5 Summary

The cost estimation on major facilities and materials is summarized by transport mode as below. The estimation is made in reference to the world market trend. However, at a time of actual procurement, a thorough study should be made on the market movement for an appropriate project decision.

Table 9.2-6 Summary: Capital Investment Amount

		LNG		CNG		Pipeline	
Demand Scenario		Case-A	Case-B	Case-A	Case-B	Case-A	Case-B
Capacity		100t/d	200t/d	100t/d	200t/d	12"	20"
Train/line		2	2	2	2	1	1
Annual LNG Equiv.	tons/year	66,000	132,000	66,000	132,000	90,000	323,000
Gas Quantity	MMcf/year	3,188	6,377	3,188	6,377	4,354	15,613
	MMcfd	9.7	19.3	9.7	19.3	13.2	47.3
Satellite Terminal							
Strage tank	Satellite-A	450kl x 2	450kl x 2	none		none	
	Satellite-B	na	2,000kl x 3				
	Satellite-C	na	80kl x 1				
Containers		none		42	336	none	
Gas Transportation							
Numbers of Trucks		20	46	44	105	none	
CAPEX (w/o Admin.cost)		$ million	$ million	$ million	$ million	$ million	$ million
Plant		90.0	140.0	20.0	32.0	na	na
Transportation		14.0	45.3	33.0	107.6	524.4	555.0
Satellite Terminal		8.2	36.7	19.1	127.7	2.6	10.3
Total		112.2	222.0	72.1	267.3	527.0	565.3

Source: JICA Study Team

Pipeline construction cost is generally affected by the natural condition along the pipeline route and passage of urban areas. For construction of a pipeline between Dar es Salaam and Dodoma, there are not so many points to cross any urban areas or to traverse rivers. Therefore, standard conditions are assumed for the civil work.

Compared with a real pipeline, the amount of CAPEX necessary for a virtual pipeline system is significantly lower when the demand is relatively small. This is because a virtual pipeline can adjust its business size flexibly and is able to closely follow changes in demand size. A real pipeline is more suitable to transport natural gas in a large volume.

As the demand expands, the investment amount for CNG exceeds that for mini-LNG system. This is because LNG in liquid status can be stored effectively under a relatively low pressure below 0.7 bar, while it is physically impossible to hold the same amount of gas under CNG condition. In addition, a small-scale LNG system can enjoy scale-merit by ramp-up while CNG only needs a greater number of the same compressor.

9.3 Economic Evaluation

(This section is withheld because of confidential information)

9.4 Summary: Cost for Gas Transport

Above observations are consolidated into project evaluation models for gas transport by way of LNG, CNG and pipeline. Then, necessary tolls for gas transport are calculated with following assumptions:

a. Feedgas price procured at Kinyerezi is $5.36 per MMBtu as announced by EWURA in

May 2017.[66]

b. Project should satisfy an IRR of 10%, with project operation period of 25 years.

c. The toll should cover all operation to make gas ready for input into city gas system after regasification or other conditioning.

The outcome of the analysis shown in Table 9.4-1 illustrates that a virtual pipeline is a highly efficient option for small quantity gas transport compared with a real pipeline.

Table 9.4-1 Total Cost for Gas Transport

Vehicle		Mini-LNG		CNG		Pipeline	
Demand Scenario		A	B	A	B	A	B
Capacity : LNG equivalent		100t/d	200t/d	100t/d	200t/d	12"	20"
Train/line		2	2	2	2	1	1
Annual LNG Equiv.	tons/year	66,000	132,000	66,000	132,000	90,000	323,000
Gas Quantity	MMcf/year	3,188	6,377	3,188	6,377	4,354	15,613
	MMcfd	9.7	19.3	9.7	19.3	13.2	47.3
Demand							
Start Demand	tons/year	28,000	64,600	28,000	64,600	27,940	62,000
Reach peak in year	in year	2035	2033	2035	2033	after 2050	after 2050
Average Load		89.5%	93.0%	89.5%	93.0%	49.8%	35.8%
Number of trucks required		20	44	46	105		
Stroage		450kl x 2	2,000 x3	42 ctnrs	348 ctnrs		
Gas Price		$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu
Feedgas Price		5.36	5.36	5.36	5.36	5.36	5.36
Plant processing		8.34	5.89	2.94	1.94	Included in transport	
Ex-plant Price		13.70	11.25	8.30	7.30	5.36	5.36
Transport		1.62	1.49	3.44	3.46	45.62	17.34
For Dodoma		1.96		4.24			
For Morogoro		0.97		2.04			
Satellite Terminal		2.68	1.54	4.54	4.63	0.47	0.45
Conversion+Transport		12.64	8.92	10.92	10.03	46.09	17.79
Ex- Dodoma Satellite Price including Feedgas Cost							
	$/MMBtu	18.34	14.75	17.09	16.17	51.45	23.15
	$/toe	728	585	678	642	2,042	919

A real pipeline is an option for gas transport of greater quantity. It should be noted that, in the above calculation, gas demand for pipeline transport is not capped to the capacity of the LNG plant for Case-A (100t/day x 2trains = 66,000 t/year) or Case-B (200t/day x 2 trains = 132,000 t/year), but is expanded to its maximum capacity of 90,000 t/year for Case-A (12”) and 323,000 t/year for Case-B (20”) as gas demand grows. Nevertheless, economics are critical for a real pipeline.

Hypothetical economics of CNG is calculated assuming that a huge number of CNG containers are procured to store 7-days inventory of gas at satellites. The calculated economics looks not bad. However, CNG requires an extremely big number of containers to hold a 7-day stock at satellites, also giving greater burden on the traffic system; this is simply unrealistic. CNG is not a suitable method to transport natural gas for destinations beyond certain distance where some amount of inventory must be held to avoid supply disruption. Nevertheless, CNG is an efficient option for delivery of gas to small scattered destinations. For example, a regular size container of 7.5 tons (1,875m^3) may last for 7 days at a user of consuming 1 ton (250 m^3) a day. If users are located in

[66] The Petroleum (Natural Gas Indicative Price) (Special Strategic Investments) Order, 2017, EWURA, 5 May 2017

a short distance within an easy reach, supply security would not matter.

Conclusion

From the above analysis, we conclude that mini-LNG is the realistic and superior option to distribute natural gas in Tanzania for city gas systems and direct bulk users. In future when a large LNG plant starts operation, the same virtual pipeline system can be used and expanded closely following the regional demand growth patterns.

With this conclusion, we will develop in the following chapters an Implementation Plan for developing a virtual pipeline system and city gas distribution network by way of mini-LNG.

Part-2 Implementation Plan: Virtual Pipeline System by mini-LNG

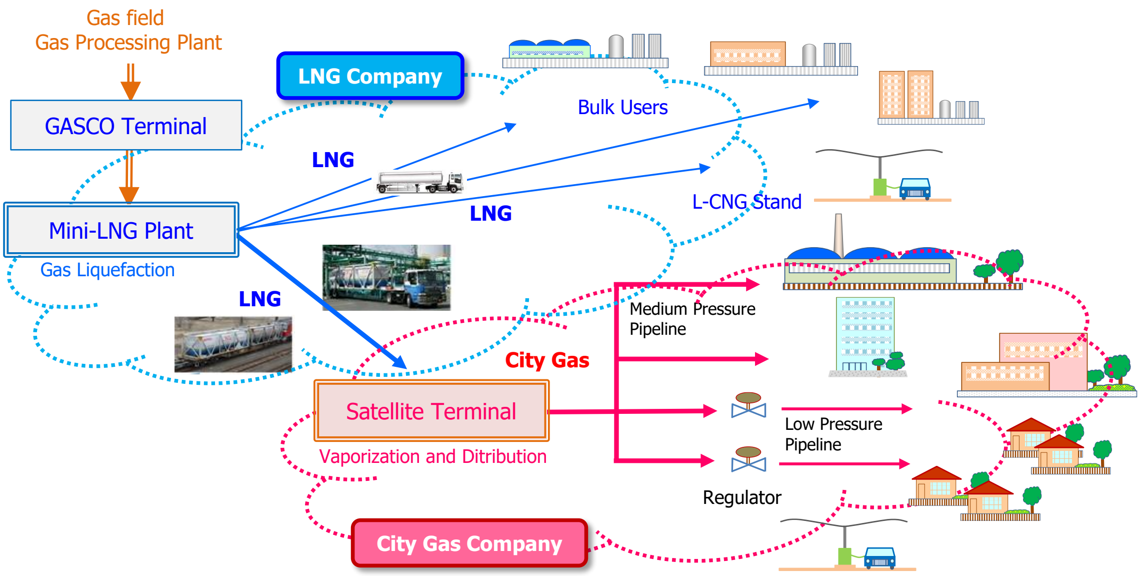
In the Part-1 study, LNG is selected as the most realistic and superior vehicle to distribute natural gas in Tanzania during the early stage of gasification when demand in regional markets are relatively small. Based on this finding, the draft Implementation Plan is developed in Part-2 for promotion of natural gas by way of LNG. Configuration of such system is developed in Chapter 10 and economic analysis is run in Chapter 11.

Chapter 10 Gas Supply System by Mini-LNG

The natural gas supply system comprises a mini-LNG plant, surface transport of LNG, satellite terminals for receiving and regasification, city gas network and Gas service stations. Configuration and features of these sectors and costs incurred there are assessed in this chapter.

10.1 Gas Flow and Business Structure

A schematic gas flow is shown in Figure 10.1-1 illustrating the natural gas supply scheme for the domestic market by way of LNG. Feedgas is obtained from the GASCO terminal at Kinyerezi and liquefied into LNG, which in turn is distributed to regional city gas companies, bulk LNG users and Gas service stations. Then, LNG is vaporized, and output gas is supplied to the city gas system or used directly at bulk users. In case of city gas, large customers may receive gas at medium pressure of 3-5 bar while smaller customers receive supply at a low pressure below 1 bar after conditioned at a regulator.



Source: JICA Study Team

Figure 10.1-1 Gas Distribution Flow and Business Coverage

The above gas business structure may be divided into two sectors save for direct bulk transport users and Gas service stations, namely, LNG supplier and city gas distributor. An LNG supplier covers gas liquefaction and LNG distribution to bulk transport users and regional city gas companies. It is responsible for LNG transport, but the job may be out-sourced to transport providers. City gas company purchases LNG on delivered basis, regasify it and distribute city gas to its users. It specializes in regional gas supply and market development within the reach of the city gas network. It may also intermediate sale of LNG for or even deliver LNG to users in adjacent areas yet to be covered by its pipeline system. It may also operate Gas service stations as appropriate, which is discussed separately in section 10.6.

In the following analysis, we assume that there will be two companies specializing in LNG production and distribution on one hand and city gas distribution on the other. Considering the above functions of respective companies, their model organization and personnel plans are drafted as shown in Figure 10.1-2 and Figure 10.1-3.

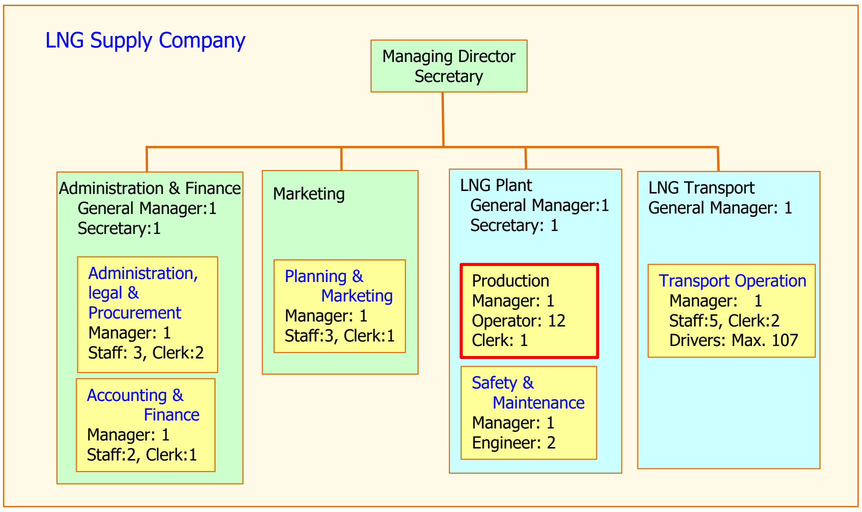


Figure 10.1-2 Organization of LNG Supply Company

The LNG Supply Company will have four major divisions under the Managing Director, namely, Administration and Finance, Marketing, LNG Production and LNG Transport. The LNG plant will be operated 24 hours a day with three shifts. LNG transport requires quite a few numbers of drivers. In view of the specific nature of the job, transport service may be out-sourced. Such being the case, however, certain staffs are necessary for distribution planning and coordination as well as site operation. It should also be noted that loading and unloading of LNG requires skilled operators as the operation needs careful monitoring and tuning-up of pressure.

The Dodoma City Gas Company will have three major divisions, namely, Administration and Finance, Marketing and Customer Relations, and Gas Plant Operations: for Case-B, there will be three gas plants at the Satellite-A at the New Government City, Satellite-B at Zuzu and Satellite-C at Iyumbu.

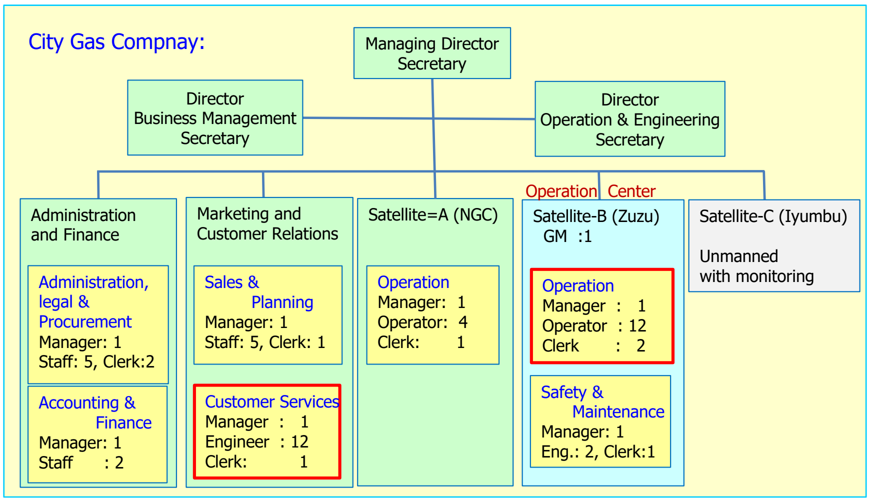


Figure 10.1-3 Organization of Dodoma City Gas Company

For Case-A where only Satellite-A is considered, Administration and Marketing Divisions are still necessary. Satellite-A may be operated one-shift a day basis, however, the customer relation section must stand-by 24 hours for emergency response. As such, if city gas demand is limited, business administration cost accounts for a relatively high portion in the city gas business.

For Case-B where all three satellites are built, Satellite-B functions as the operation centre and look after Satellite-A and Satellite-C. Satellite-B will be operated 24 hours a day to closely respond to hour to hour load fluctuations in gas supply to the Zuzu power station. Satellite-A will be operated on one-shift a day basis. Satellite-C will not have permanent staff; operators from Satellite-A or B will attend when LNG is received there.

Based on the organization and personnel plan as above, necessary office space is roughly estimated as follows.

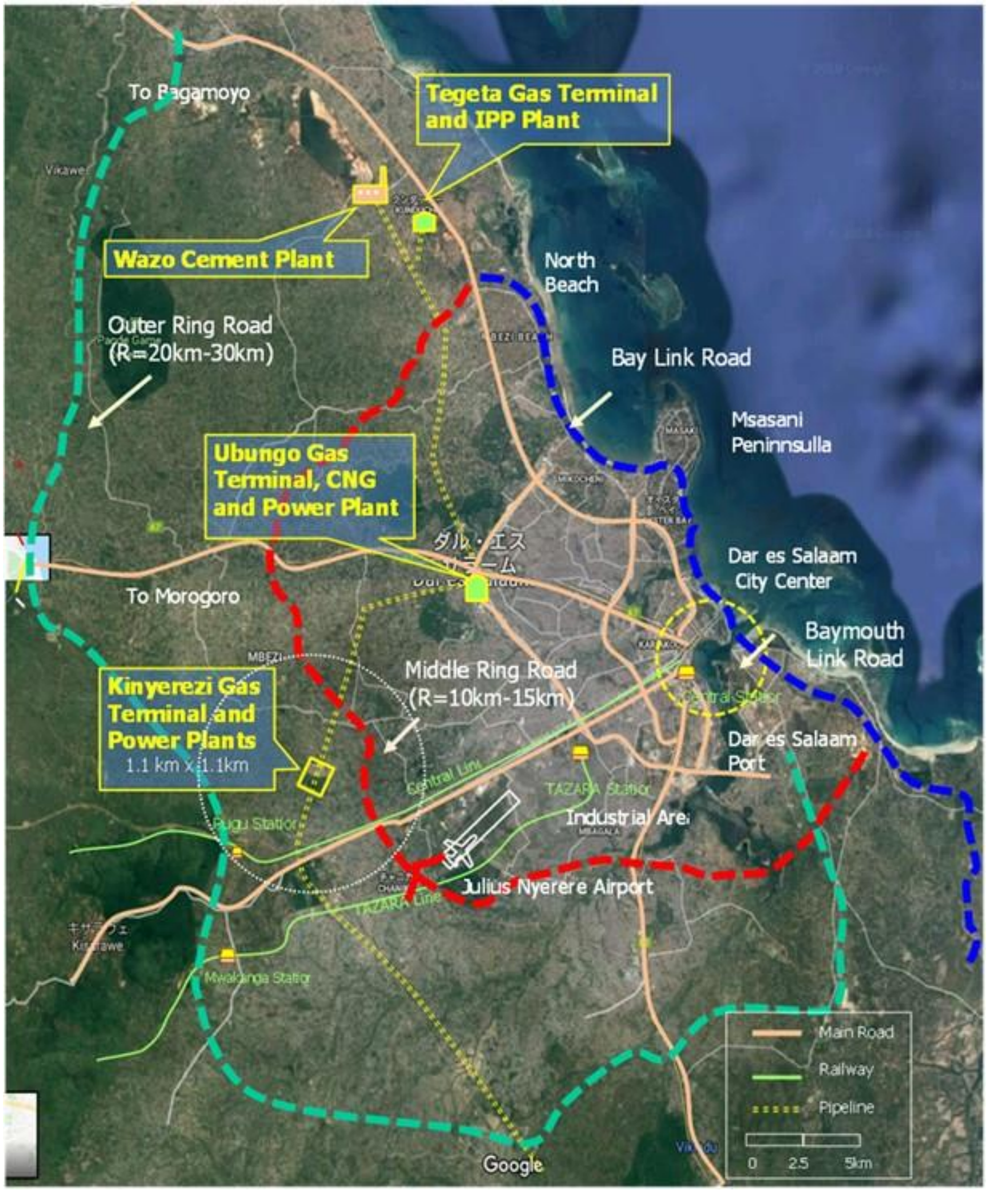
Table 10.1-1 Office Space

LNG Company			City Gas Company		
Headquarters	600	m^2	Headquarters	1,000	m^2
LNG Plant	600	m^2	Satellite-A	100	m^2
Transport Operation	300	m^2	Satellite-B	400	m^2
			Satellite-C	100>	m^2
Total	1,500	m^2	Total	1,600	m^2

10.2 Mini-LNG Plant: Feedgas and Gas Processing

10.2.1 LNG plant location

The Kinyerezi Energy Complex is selected as the candidate site for the LNG plant to be the origin of the new gas supply system. It is located about 3 km northwest of the Dar es Salaam airport; the Kinyerezi-1 and Kinyerezi-2 gas power plants are operating there. The trunk gas pipeline from gas fields arrives there with sufficient supply capacity.



Source: JICA Study Team – work on Google Map

Figure 10.2-1 Kinyerezi and Dar es Salaam Urban Transport Master Plan Final Draft

The site for a mini-LNG plant may need to satisfy the following conditions;

1) It should be located within 2 km or so from the existing gas pipeline or a new gas field to be developed in the vicinity of Dar es Salaam.
2) It is possible to connect a branch line from the above facility.
3) Frequent transit of heavy vehicles is possible
4) A space roughly 200m x 200m is available.

Concerns on the site are as follows:

1) If sufficient space is available for construction of an LNG/CNG plant as construction of the Kinyerezi-3 and -4 power plants is scheduled there, though a mini-LNG plant will

be relatively small.

2) The site is surrounded by vast residential areas. It is distant from the main roads without wide connection roads. Presently it seems difficult to run heavy vehicles frequently.

Under the circumstance, construction of a 2 km gas pipeline is scheduled as contingent in the budget for the economic evaluation to allow an alternative plant location.

Despite the current status, however, the Kinyerezi Gas Terminal is located at a strategically advantageous point for virtual pipeline system. It is located close to the future Middle Ring Road and Outer Ring Road according to the Dar es Salaam Urban Transport Master Plan Final Draft (July 2018, JICA) as shown in Figure 10.2-1, as well as the new standard gauge railway, the central line of the TRL and the TAZARA line. They are mostly within a range of 5km or so.

Since the virtual pipeline system uses container trailers, superior road system is essential. In this regard, Kinyerezi is located at an ideal point. As the gas demand grows in future, these containers can be transported by railway, which requires not a specific facility but only a general freight yard with side-tracks for loading containers onto flat rail wagons. This will substantially improve transport efficiency and reduce burden on the road transport system.

Source: JICA Study Team – work on Google Map

Figure 10.2-2 Closer View of Kinyerezi Energy Complex

The Kinyerezi energy complex has a land of 1.1km x 1.1km as shown in Figure 10.2-2. The GASCO's gas terminal and TANESCO's Kinyerezi-1 and -2 gas power plants are already operating there. While the Kinyerezi-3 and -4 power plants are scheduled, land required for construction of a small gas processing plant and shipping facilities is relatively small. Therefore, Kinyerezi may become a convenient origin of the gas supply system once the above road plans are materialized and an access road is constructed.

10.2.2 Main Facility of LNG Plant

Main facilities of a mini-LNG plant comprise pre-treatment system, liquefaction system, storage tank and shipment facilities as follows:

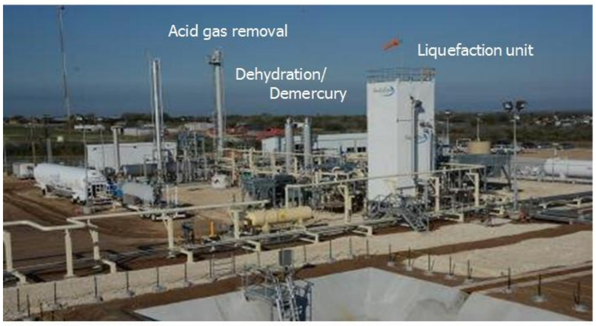
1) Pre-treatment
- Acid gas removal
- Dehydration and mercury removal

2) Liquefaction
- Main Cryogenic Heat Exchanger
- Refrigerant System

3) Utilities

4) LNG Storage

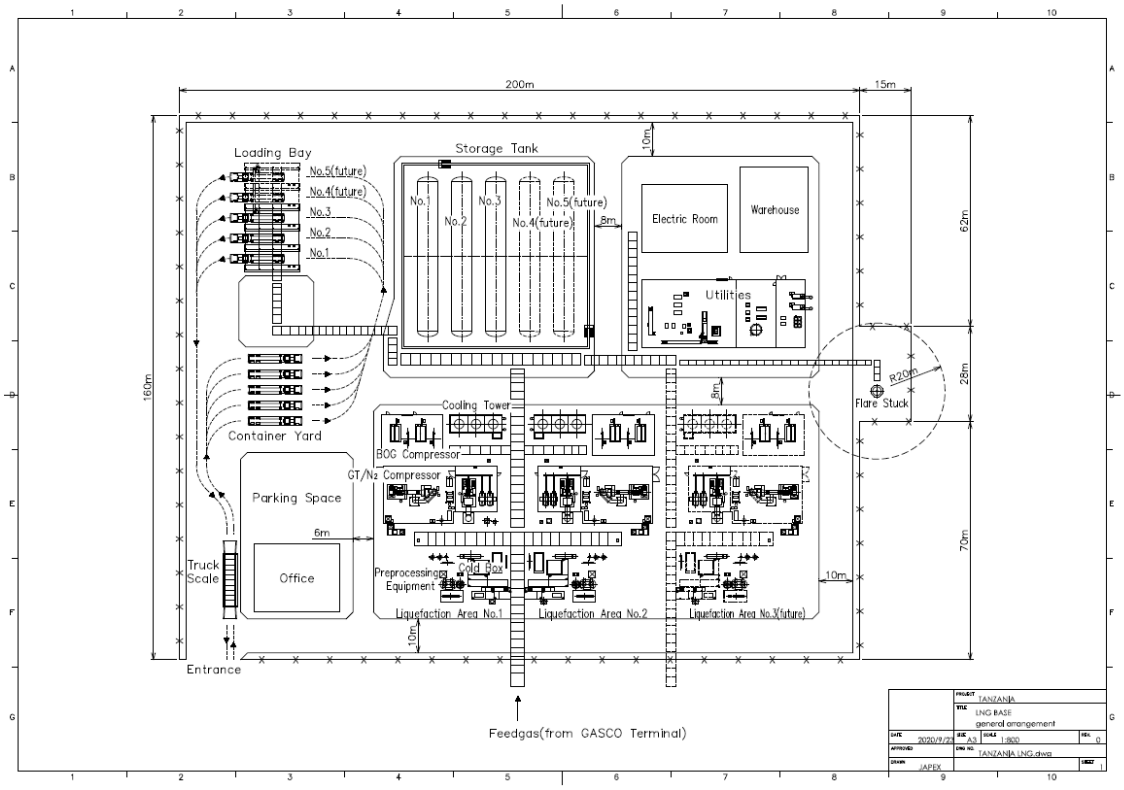
5) LNG Loading



Source: Chart E&C

Figure 10.2-3 Mini-LNG Plant

A list of main facilities for a 200 tons per day x 2 trains model plant is shown in Table 10.2-1 and a schematic plot plan with a reserved space for another train as below.



Source: JICA Study Team

Figure 10.2-4 Plot Plan for Mini-LNG Plant

Table 10.2-1 Main Facilities of a Mini-LNG Plant

Section	Facility	Critical Equipment
Office	General & Administration	
	Contorl Room	Plant Control System
Pre-treatment	Acid Gas Removal	Absorber (Tower)
		Amine Regenerator (Tower)
	Dehydratoer/Mercury Removal	Molecular Sieve
		Mercury Removal Bed
Liquefaction	Liquefaction	Main Cryogenic Heat Exchanger
		Compressor/Expander
	Refrigerant cycle	Air Separator to produce N_2 as refrigerant
		Refrigerant Cooler & Driver Motor
Utilities	Power	Gas Engine Generator (~10MW)
	Fuel	Fuel Gas
	Instrument	Plant/Instrument Air System
		Hot Water System
	Flare	Stack
		Knock-out Drum
Storage	Storage Tank	Pressurized LNG Storage (600 m3 x 3 Units; <-160 C, 0.2-0.7 MPa)
		Boil-off Gas Recovery
Loading	Loading System	Truck Weight Scale (2-4 Lanes)
	(60-90 minutes to load one LNG container)	Cryogenic Loading Hose
		Return Gas Recovery
		(LNG pump: not considered as LNG storage tank is pressurized)
	Truck yard	No reverse!
	In case of rail transport	Top Lifter
	Spare Trailer/Container at hand	50% - 100% of containers for daily shipping

Source: JICA Study Team

Feedgas is obtained from the GASCO's Kinyerezi Terminal. It is a high quality gas of commercial grade. However, it needs to be pre-treated before liquefaction to remove acid gas, water and mercury to qualify the LNG grade. Then, it will be liquefied using nitrogen as the refrigerant, which is obtained from the air separator.

LNG as product will be stored before shipment. Pressurized storage tanks of 600kL x 3 will be built to hold 3~5-day production; tank size may be changed according to the production capacity of the plant. LNG will be stored below 160 degree C under pressure of 0.2-0.7 MPa. LNG pump is used for loading. As it is pressurized, LNG pump is not necessary for unloading, which makes the operation easier.

Then LNG will be loaded into containers for shipment. It takes 60-90minutes to load one LNG container of 18 tons; 5-7 containers may be loaded a day with one bay for 8 hours operation. For safety reason, reversing of an LNG lorry is not allowed in Japan. Enough space is necessary at the yard to allow safe turning of long lorries.

The total space for the above plan is 160m x 200m with a future plan for another train. The location of the flare stack to observe the safety regulation is one of the key factors to define the necessary space.

10.2.3 Plant Size

10.2.4 Notes on the Plant Plan

10.2.5 Operation of LNG Plant

(These sections are withheld because of confidential information.)

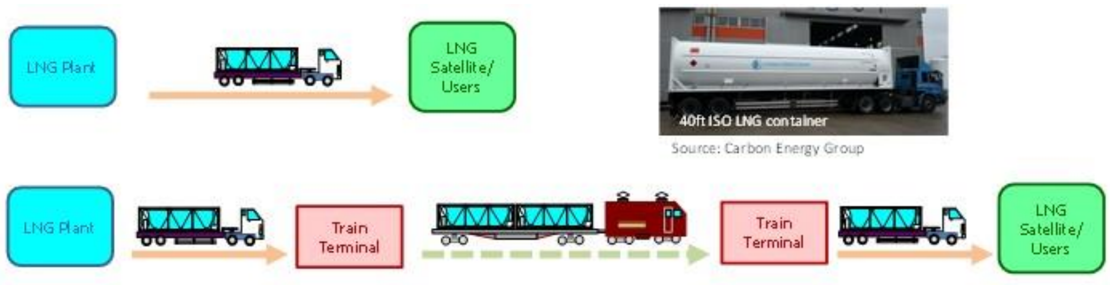
10.3 Transport of LNG

10.3.1 Vehicles for Transport

Vehicles used for land transport of LNG are as follows:

a. Road: Tank-truck (lorry), Trucked-trailer, Container on trailer chassis
b. Rail: Container (ISO 30ft, 40ft) on flat wagon

Tank trucks are usually used for short/medium distance transport, while, if rail service is available, railway is an efficient option for medium/long distance transport over 300km. Containers can be used for both purposes.



Source: JICA Study Team

Figure 10.3-1 Land Transport of LNG

In this study, we assume use of 40ft ISO LNG containers with the specification as below[67]:

a. Size: Width 2.5m x Height 2.5m x Length 12m
b. Weight: Deadweight 12 t + Payload 18t (at 95% load) = 30t
c. Working Pressure: 0.3-0.6 MPa (maximum < 1.0 MPa)
d. Boil-off rate: 0.15-0.30% per day
e. Long holding period: 90 days
f. Total length including trailer-head and chassis: 16.5m
g. Turning radius: 9.4m
h. Required road width for 90 degree turn: 8.3m

In view of the extreme conditions on the temperature and pressure of the handling materials, the LNG tank must be designed, manufactured, inspected and maintained strictly according to international standard and safety regulations. Prices of vehicles CIF Tanzania are estimated at

[67] JAPEX, Carbon Energy Group, Isuzu, etc.

$100,000 for a trailer head and $200,000 for a set of container and chassis. On top of the imported CIF price, there will be about 50% tax and levy for procurement of a new vehicle.[68]

Source: JAPEX

Figure 10.3-2 Toplifter and Rail Transport

In case railway service is available, same containers are usable. After filling at the LNG plant, they are transferred to the originating railway freight station by trailers, loaded onto flat wagons using a toplifter, transferred to the destination station, unloaded by a toplifter and finally delivered by trailers to satellite terminals or directly to bulk users. LNG containers are transported by a combination of trailers and railway; no service line is necessary. In future when transport requirement increases, rail transport will become an efficient option to integrate operation and ease the burden on the road traffic.

10.3.2 Transport Operations

The road distance between Dar es Salaam and Dodoma is about 470km and the round trip by a lorry may take two days. Loading at the LNG plant takes one and a half (1.5) hours, traveling the distance takes eleven (11) hours including breaks, and unloading at the satellite terminal in Dodoma takes one hour. It takes seven hours to Morogoro and 14 hours to Dodoma to complete unloading at the destination. Two drivers are assigned to one trailer. Considering drivers' holidays and contingent schedule change, twelve (12) round trips per month is assumed in this study. This compares to 24 days operation per month or 80% utilization of the vehicles.

Table 10.3-1 Round Trip to Dodoma

	Dar es Salaam to Dodoma			Return	
			houors		hours
Dar es Salaam : Loading	km	km/h	1.5		
DSM to Chalinze	106	40	2.7	↑	2.7
Chalinze to Morogoro	84	50	1.7	↑	1.7
Morogoro	190		5.8	↑	
Morogoro to Dodoma	280	60	4.7	↑	4.7
Break			2.0		2.0
Dodoma: unloading			1.0		
Total	470		13.5		9.0

As the loading operation takes time, trucks can depart only one by one. For example, daily

[68] See Section 8.2.2

loading may be scheduled for 6:00, 7:30, and 9:00 in the morning at three bays. In this case, only 162 tons (18t x 9 cargoes) of LNG can be shipped a day and the last truck can complete its job near midnight at the destination. In order to avoid overwork of drivers and operators while securing smooth and stable operation, it is necessary to structure the loading and transport job programme carefully. There may be several means to ease the operation congestion such as to set up a driver relay point in between the origin and destinations, keep some surplus vehicles for pre-loading, assign the loading job to the plant staff, etc. For appropriate planning of the shipping schedule, it is also important to closely monitor the inventory status at the receiving terminals and bulk users. After unloading at user's site, it would not be allowed to keep the empty truck there. If overnight operation is necessary for delivery of LNG to direct bulk users, it is necessary to prepare some accommodation for vehicles.

As the volume expansion factor of LNG is extremely large (592 times from liquid to gas for the Songo Songo gas), it is very important to maintain the pressure balance of the BOG and LNG during the loading and unloading operation. Thus these operation takes time compared with petroleum products such as gasoline. Valves and gauges for loading and unloading operation are located at the rear or the side of the LNG tank. Because of the high volume factor and to protect important apparatus, reversing of an LNG tank truck is not allowed by safety regulation to avoid any serious incident. Therefore, sufficient space must be prepared for turning of a very long vehicle, for example 15m of turning radius with a 10m wide lane.

Source: JICA Study Team

Figure 10.3-3 Valves and Gauges of LNG Tank-truck/container

10.3.3 Education and Training

Because of the specific feature of LNG as below, thorough training of drivers is necessary to secure safe operation.

a. Reversing of an LNG truck is not allowed
b. LNG is always handled in a tightly closed system, not opened to the air
c. Pressure control is needed during loading and unloading operation.
d. Professional knowledge is needed to handle materials at a cryogenic temperature, in

particular for proper response at any incident.

- Never touch anything by bare hands
- During the loading and unloading operation, moisture in the air produces fog but not smoke because of an extremely low temperature.
- Inside the closed system, LNG is boiling off at any time.
- When LNG gasifies, methane is lighter than air and diffuses fast; just in case for unexpected leakage, open air operation is preferred for safety.

e. Safe driving and speed limit must be strictly observed.

Training of drivers on knowledge on LNG and its safe handling method may need at least 3-6 months. On-site training must be conducted in advance.

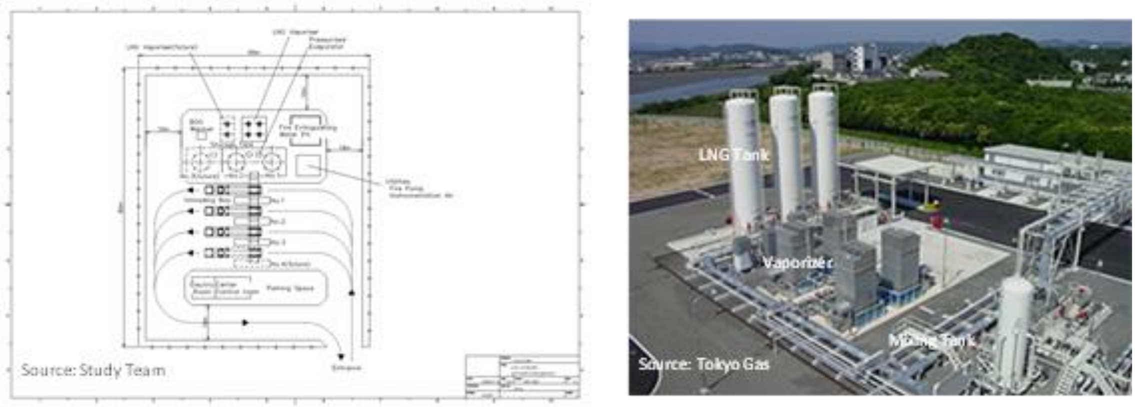
10.4 Satellite Terminals to Receive LNG and Dispatch City Gas

10.4.1 Facilities at Satellite Terminal

A typical set of facilities at an LNG satellite terminal will be as follows:[69] some of them such as LNG pump, mixing tank and BOG Humidifier are not essential.

a. Trailer/truck Parking Space
b. LNG Receiving Unit with connection flanges, valves, pressure meters, flow meters, etc.
c. LNG Pump if high pressure transfer is designed
d. PBU (Pressure Buildup Unit) for tank and lorry operation pressure adjustment
e. LNG Storage Tank(s)
f. LNG Vaporizers (at least two units)
g. Pressure Regulator (primary, secondary)
h. Mixing Tank to receive and store vaporized gas before pressure adjustment for outlet
i. Gas Flow Meter and other information and communication system
j. BOG Humidifier
k. Nitrogen Unit for gas purge
l. Office

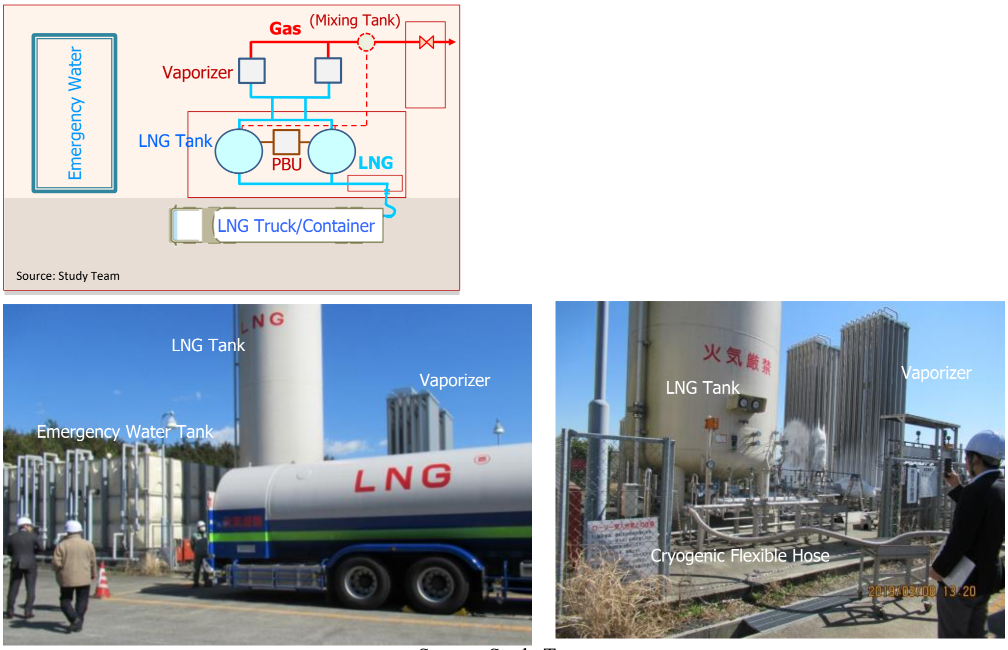
[69] Air Water & Plant Engineering Inc. "LNG equipment & facilities", http://www.awpe.co.jp/english/



Source: JAPEX, Tokyo Gas

Figure 10.4-1 LNG Satellite Terminal

In Japanese LNG satellites, LNG storage is designed to hold 5-7 day supply, which defines the required storage tank capacity. If the LNG plant is remote and LNG delivery in adjacent area is not so frequent, more stock may be necessary. Ambient air draft type vaporizers are common for mild-hot countries while steam bath type vaporizers are used in colder countries. Discharge pressure is 0.15 ~ 0.20 MPa.



Source: Study Team

Figure 10.4-2 LNG Satellite Terminal: Medium/Small Satellite

Typical plant sizes defined by the regional demand summarized by a Japanese city gas company is shown in Table 10.4-1. They are aimed at isolated industrial and commercial users. Since LNG delivery in the Japanese market is popular and frequent, it is relatively easy to obtain supplemental supply if consumption goes at a high pace. Therefore, stock level is set at a relatively low range of 5 - 7 days.

Table 10.4-1 Sizes of LNG Satellite Terminals

Annual Consumption	tons	500	1000	2000	3000	4000	5000
Daily Average (300days/year)	tons	1.7	3.3	6.7	10	13.3	16.7
Storgae	tons of LNG	15	20	30	40	50	60
	kl	50 x 1	60 x 1	100 x 1	60 x 2	80 x 2	100 x 2
Space excluding parking	(m x m)	10 x 10	10 x 12	12 x 14	16 x 18	16 x 18	18 x 18
Safety Distance from:	Schools, hospitals	21.0	22.4	27.2	29.3	33.1	36.6
(in addition)	Houses	14.0	14.9	18.1	19.5	22.1	24.4
Equivalent Fuel	LPG (t)	540	1,090	2,170	3,260	4,340	5,430
	Diesel (kl)	700	1,390	2,780	4,170	5,570	6,960

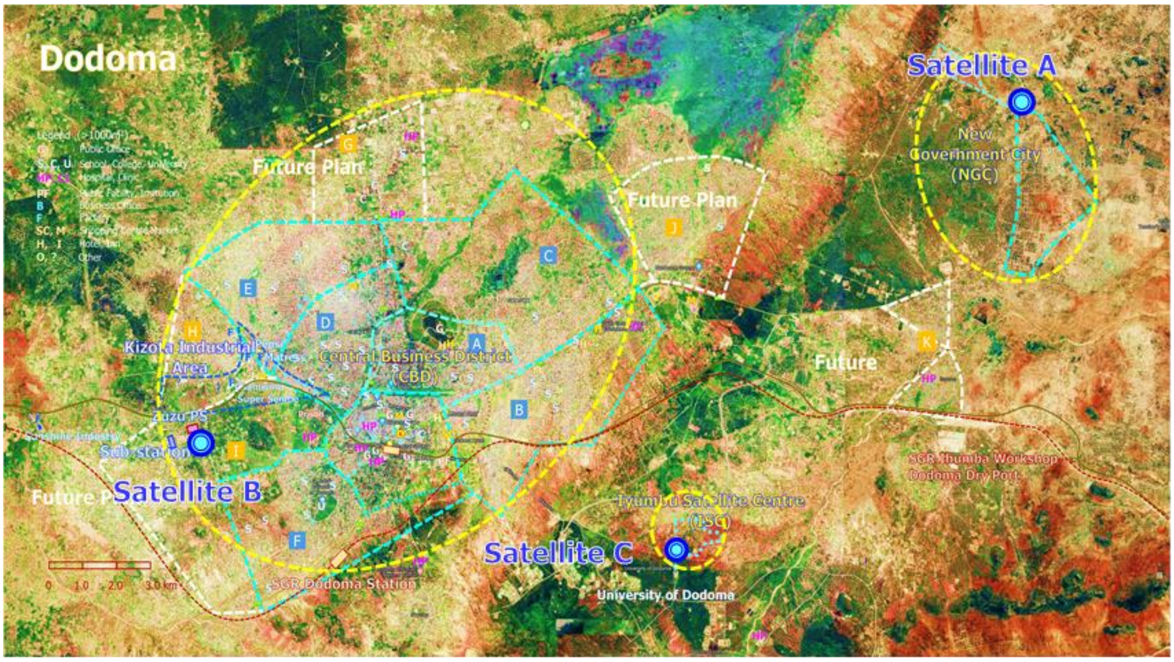
Source: Saibu Gas

1. Safety distance is derived subject to the Japanese regulation.
2. Heat values are LNG: 54.41 MJ/kg, LPG: 50.23MJ/kg, Diesel: 39.10MJ/ltr

For an NGV gas station to use LNG as gas source, similar facilities may be considered for gas supply. Compared with the space of a typical petrol station including refuelling bays with dispenser, mechanic pit and office, for example 30m x 40m, the space necessary for LNG storage and gasification is relatively small. On the other hand, it is necessary to prepare sufficient space for parking and turning of a container-trailer.

10.4.2 Satellite Terminals for Dodoma City Gas Development

Three satellite terminals are considered for the city gas supply project in Dodoma as shown in Figure 10.4-2; Satellite-A for New Government City, Satellite-B for the Dodoma City centre CBD gasification project and Satellite-C for Iyumbu Satellite Centre development. At the beginning, these terminals will be operated separately without pipeline connection. As city gas coverage areas expand in future and come closer each other, they may be connected.



Source: JICA Study Team – work on Google Map

Figure 10.4-3 Satellite Terminals for Dodoma City Gas Plan

Case-A of this study considers city gas development only for the New Government City. This is intended to examine the scale effect of the project on a variety of demand size. In this section, we mainly discuss Case-B where three satellite terminals will be operated simultaneously with different terminal specifications. As the base information, the amount of LNG regasified and delivered at satellites are summarized in Table 10.4-2 from the analysis in Chapter 9. For designing purpose, annual consumption is rounded to thousand tons.

Table 10.4-2 Gas Requirement at Satellites

									Desgin allowance at	20%
Location		Annual Consumption			Daily	350	day/year	Hourly	8	hour/day
		2025	2030	Design	2025	2030	Design	2025	2030	Design
		t	t	t	t/day	t/day	t/day	t/hour	t/hour	t/hour
Satellite-A	City Gas	4,070	10,260	11,000	11.6	29.3	31.4	1.70	4.40	4.80
Satellite-B	City Gas	5,520	12,760	13,000	15.8	36.5	37.1	2.40	5.50	5.60
	Zuzu Power	31,600	63,200	63,000	90.3	180.6	180.0	13.50	27.10	27.00
	Total	37,120	75,960	76,000	106	217	217	15.90	32.60	32.60
Satellite-C	City Gas	400	1,000	1,000	1.1	2.9	2.9	0.20	0.40	0.50
Total		41,590	87,220	88,000	119	249	251	17.80	37.40	37.90

In view of the demand level, required capacity of vaporizers and storage tanks are calculated as shown in Table 10.4-3 and 10.4-4. For calculation of the required capacity of vaporizers, hourly gas sending out is calculated assuming 350 day a year and 8 hours a day operation and 20% allowance is considered for demand fluctuation. At least two (2) units of vaporizers are installed at each location to ensure stable operation.

Table 10.4-3 Capacity of Vaporizers

Year			2025				2030: Design			
Location			A	B: CG	B:CG+PS	C	A	B: CG	B:CG+PS	C
Average consumption		t/hour	1.70	2.40	15.90	0.20	4.80	5.60	32.60	0.50
Vaporizer	Capacity	t/hour	1.0	1.0	10.0	0.3	1.0	1.0	10.0	0.3
	Unit		3	4	2	2	5	6	4	2
	Total	t/hour	3	4	20	0.6	5	6	40	0.6
Average Load		%	57%	60%	80%	33%	96%	93%	82%	83%

The required storage tank capacities are calculated assuming that 7-days inventory should be held with an average stock level of 70%. At the LNG unloading operation, it is necessary to simultaneously fine-tune the gas pressure in the LNG tank. For this purpose, 10% allowance is considered for ullage.

However, in Case-B where a large storage capacity is installed at Satellite-B, storage tank capacities at satellite-A and C can be set at minimal as supplemental supply may be sought from Satellite-B when such need arises. As LNG is transported frequently by containers, it would not be a problem to divert some of them to other destinations if such requirement arises.

Table 10.4-4 Capacity of Storage Tank

Year			2025: Starting Capacity				2030: Design Capacity			
Location			A	B: City Gas	B: CG +PS	C	A	B: City Gas	B: CG +PS	C
Daily consumption		tons	11.6	15.8	106.1	1.1	31.4	37.1	217.1	2.9
SG	0.427	kL	27.2	36.9	248.4	2.7	73.6	87.0	508.5	6.7
Required Capacity		kL	400	500	3,000	30	900	1,000	6,000	80
LNG Tank	Capacity	kL	450	500	2,000	80	450	500	2,000	80
	Units		1	1	2	1	2	2	3	1
	Total	kL	450	500	4000	80	900	1000	6000	80
Inventory days			16.5	13.5	16.1	29.9	12.2	11.5	11.8	12.0
Inventory		7 days	Stock level	70%	Ullage	10%				

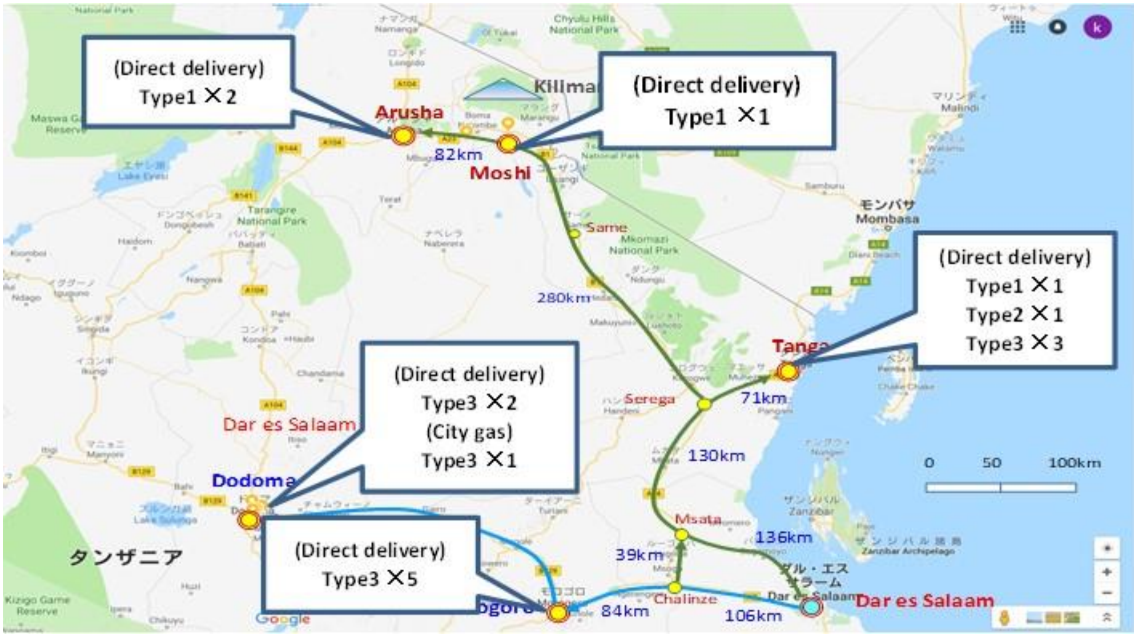
From the above calculation, construction costs of city gas satellite terminals are estimated as shown in Table 10.4-5. In addition to the cost for hardware such as tank and vaporiser, other costs are considered for other equipment, piping installation, electric and instrumentation, civil and building, commissioning, engineering and construction.

(Table 10.4-5 is withheld because of confidential information.)

10.4.3 Satellite Facilities for Bulk Transport Users

((Table 10.4-6 is withheld because of confidential information.)

In Chapter 7, we have picked up from the Regional Energy Demand Survey those factories in the object regions with monthly fuel consumption of more than 20 tons oil equivalent, or delivery of more than one LNG container per month. These energy consumers can be candidates for switching to LNG by bulk transport; they are distributed as shown in Figure 10.4-3. In addition to them, large energy users of the services sectors such as large office buildings, hotels, hospitals, commercial facilities and schools may switch to LNG. On the other hand, cement and lime factories using cheap fuels such as coal and petro-coke are excluded from the candidate since natural gas would not be commercially competitive. However, as LNG plant size affects its economics significantly, it is an important policy to take up large industry uses as much as commercially viable.



Source: JICA Study Team – work on Google Map

Figure 10.4-4 Candidate Factories for LNG Direct Delivery

Sizes of satellite facilities at these factories are estimated as shown in Table 10.4-5 including those located in Mbeya and Mwanza. Factories located remote from the system under consideration in this study may switch to LNG if conditions are favourable compared with the present fuel supply. Such potential should be investigated in the course of formulating the final project plan.

Table 10.4-7 Potential LNG Users for Bulk Transport

Large factories with monthly fuel demand more than 20 toe		Products	Fuel Demand (toe)			Fuel Demand (LNG)		Requirement		LNG Consumption		Delivery	Satellite	
			2018	2025	2030	2025	2030	Storage	Vaporization	Day	Week	per week	Type	Units
			toe	toe	toe	t	t	KL	t/hour	t	t			
Arusha	Tanzania Brewary Ltd.	Beer	404	600	800	510	680	10	0.19	1.5	10.8	1	Type1	1
	A to Z Textile	Textile	417	600	800	530	680	10	0.19	1.5	10.8	1	Type1	1
	Sub-total		821	1,200	1,700	1,040	1,430							
Dodoma	Sunshine Industrial Limited	Cooking oil	4,459	6,700	9,000	5,620	7,550	104	1.99	15.9	111.4	8	Type3	2
	Sub-total		4,459	6,700	9,000	5,620	7,550		0.00					
Mbeya	Tanzania Brewary Ltd	Beer	526	800	1,100	670	930	12	0.22	1.8	12.4	1	Type2	1
	Sub-total		526	800	1,100	670	930							
Morogoro	21st Century Textile	Textile	6,517	9,800	13,100	8,210	10,980	152	2.90	23.2	162.6	11	Type3	3
	Alliance One Tobacco	Tobacco	1,381	2,100	2,800	1,750	2,350	31	0.60	4.8	33.8	3	Type3	1
	Tanzania Tobacco	Tobacco	2,258	3,400	4,500	2,850	3,780	53	1.01	8.1	56.7	4	Type3	1
	Sub-total		10,157	15,300	20,400	12,800	17,100							
Moshi	Bonite Bottlers	Soft drinks	568	900	900	720	760	10	0.19	1.5	10.8	1	Type1	1
	Sub-total		568	900	900	720	760							
Mwanza	Mwatex	Textile	2,036	3,100	4,100	2,570	3,440	48	0.92	7.3	51.3	4	Type3	1
	Nyakato Steel Mills	Steel	1,064	1,600	2,100	1,340	1,760	25	0.47	3.8	26.6	2	Type2	1
	Mwanza Wines	Wine	1,057	1,600	2,100	1,340	1,760	25	0.47	3.8	26.6	2	Type2	1
	Sayona Drinks	Soft drinks	1,316	2,000	2,600	1,660	2,180	31	0.60	4.8	33.8	3	Type3	1
	Serengetti Brewaries	Beer	11,443	17,200	23,000	14,420	19,270	265	5.08	40.7	284.6	19	Type3	5
	Nayanza bottling	Soft drinks	627	900	1,300	790	1,090	15	0.29	2.3	16.0	2	Type2	1
	Sub-total		17,542	26,400	35,300	22,100	29,580							
Tanga	Gulam Patter Coconut Oil	Cooking oil	761	1,100	1,500	960	1,260	18	0.35	2.8	19.6	2	Type2	1
	Kilimanjaro Cement	Cement	6,065	9,200	12,300	7,700	10,310	142	2.72	21.7	152.1	11	Type3	3
	Tanga Cement	Cement	65,322	98,900	132,300	82,840	110,840	1,525	29.23	233.8	1,636.6	110	Type4	2
	Tanga Fresh	Milk products	322	500	700	410	590	8	0.16	1.3	8.9	1	Type1	1
	Neelkanth Lime Ltd	Lime	5,754	8,700	11,700	7,300	9,810	135	2.59	20.7	144.9	10	Type3	3
	Sub-total		78,223	118,400	158,400	99,190	132,710							
Total	7 cities		112,295	169,700	226,800	142,110	190,010							
	5 cities		94,228	142,500	190,400	119,350	159,520							
	5 cites excl. Cement and Lime		17,088	25,700	34,100	21,530	28,570							

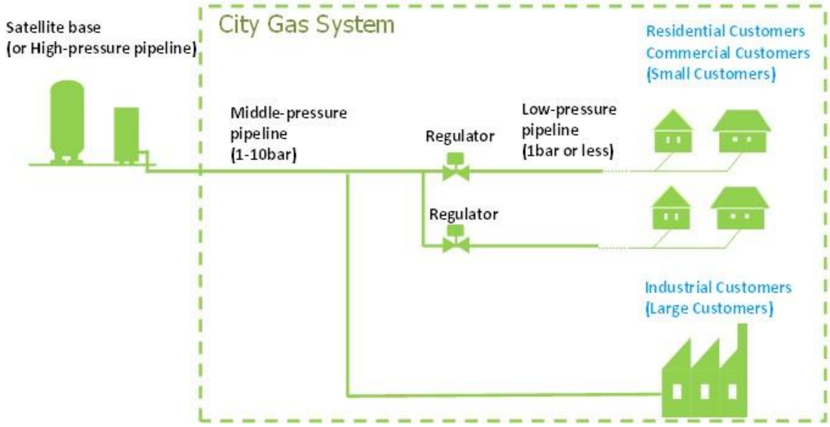
10.5 City Gas Supply System

The city gas supply system is a facility for delivery of city gas to consumers. The facility consists of medium pressure gas pipelines (1-10 bar) installed under road, pressure regulators for reducing the gas pressure from medium to low, and the low-pressure gas pipelines (lower than 1 bar) connected to customers, and the central control system. A conceptual diagram of the city gas supply system is shown in Figure 10.5-1.

Users of city gas are classified into three categories: residential (household), business and commercial (office building, public facilities, commercial facilities, hospitals, schools, etc.), and industry (factories). Medium pressure gas is directly supplied to large-scale customers such as factories and large-scale commercial facilities that consume large amounts of gas. For particularly large users such as power plants and large factories, gas will be supplied in a large volume at a high pressure, which requires special facility to condition gas such as compressors.

In this section, construction costs are estimated on the city gas supply systems for three supply areas, namely, New Government City, Central Business District of Dodoma city, and Iyumbu

Satellite Centre as described in Chapter 7.



Source: JICA Study Team

Figure 10.5-1 Conceptual Diagram of City Gas Supply System

10.5.1 City Gas Plan-A: New Government City

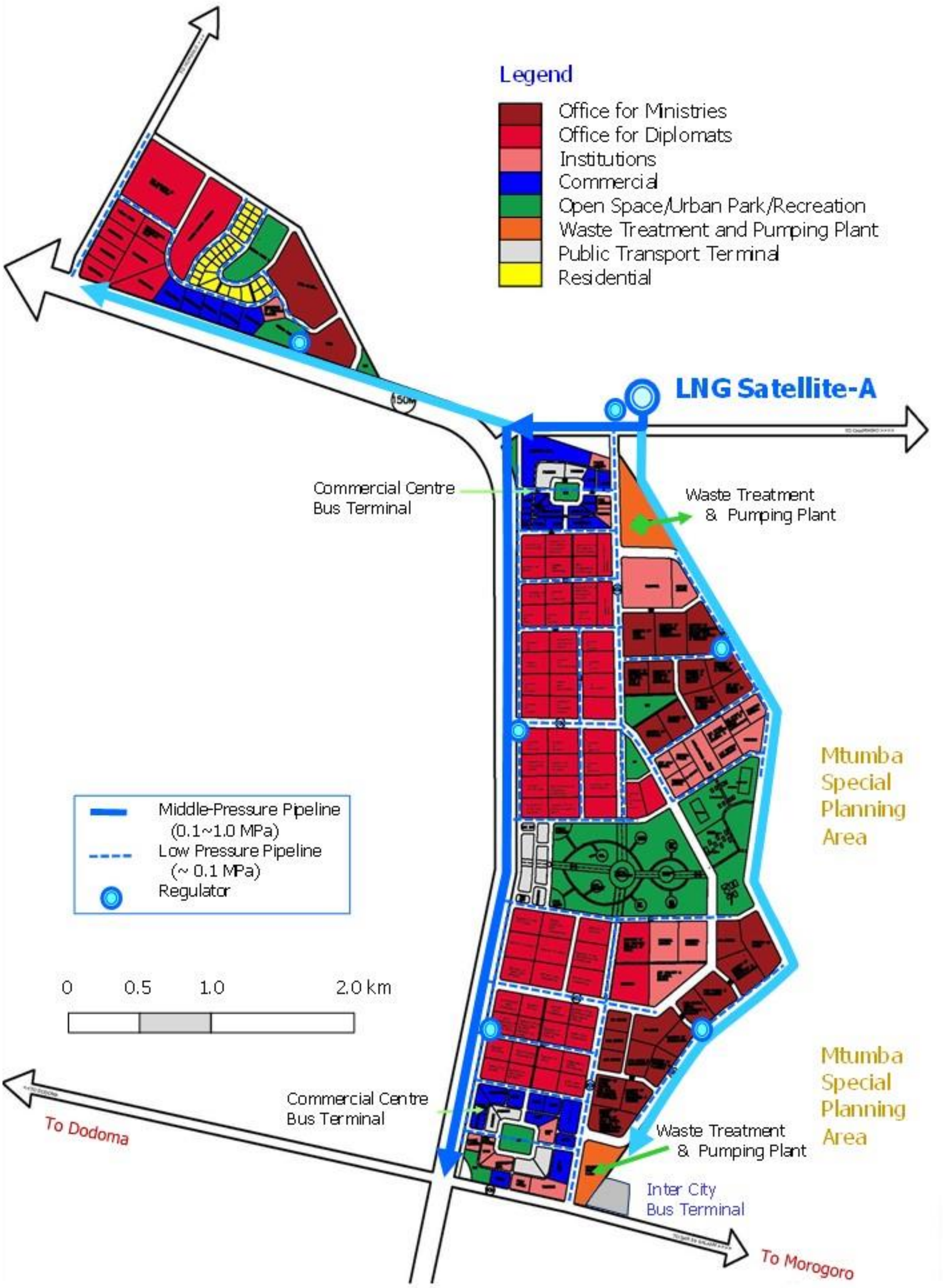
City Gas Plan-A assumes city gas supply to the New Government City, which is under construction in Ihumwa located 17 km east of the Dodoma city centre.

Figure 10.5-3 shows a plot plan of the gas pipeline installation. As the New Government City is being developed in the suburbs open space, it is possible at present to draft an ambitious and flexible plan such as introducing CHP (Combined Heat and Power) at large government offices and public facilities as providers of an anchor gas demand with high energy efficiency. In addition, there is no need to dig up roads, suggesting fewer construction problems and shorter work time compared to the established urban areas.

In this project, we assume that an LNG satellite receiving terminal A will be built at the New Government City as shown in Figure 10.5-3 and city gas will be supplied from this terminal through a medium-pressure pipeline. Large users will receive gas directly from this line. For others, gas is depressurized by regulators for supply to all areas through a low-pressure conduit. The supply facilities required for the project are a) 15km medium-pressure pipeline, b) 30km low-pressure pipeline, and c) 6 regulators as illustrated. Applying the construction cost observed in Japan for these facilities, the total construction cost of the supply facilities is estimated to be about \$ 14 million as shown in Table 10.5-1. The city gas pipeline will be installed in the underground along with the New Government City construction, so there is no redundant job to peel off the existing pavement and re-pave the road. As civil work is expensive in Japan, these estimates may be on a higher side.

Source: JICA Study Team

Figure 10.5-2 Construction at New Government City (November 2018)



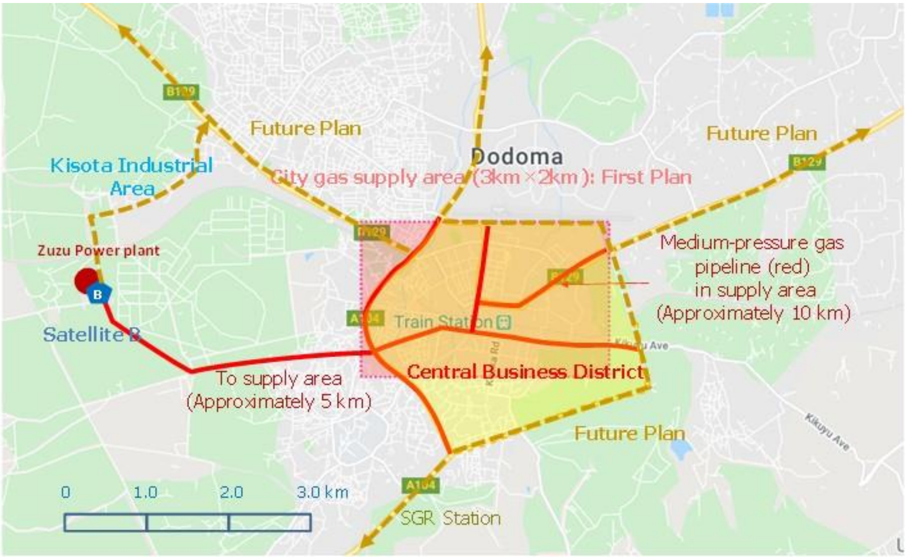
Source: JICA Study Team based on Dodoma Capital City Master Plan (2019-2039)

Figure 10.5-3 Gas Pipeline Installation Plan: City Gas Plan-A

(Table 10.5-1 is withheld because of confidential information.)

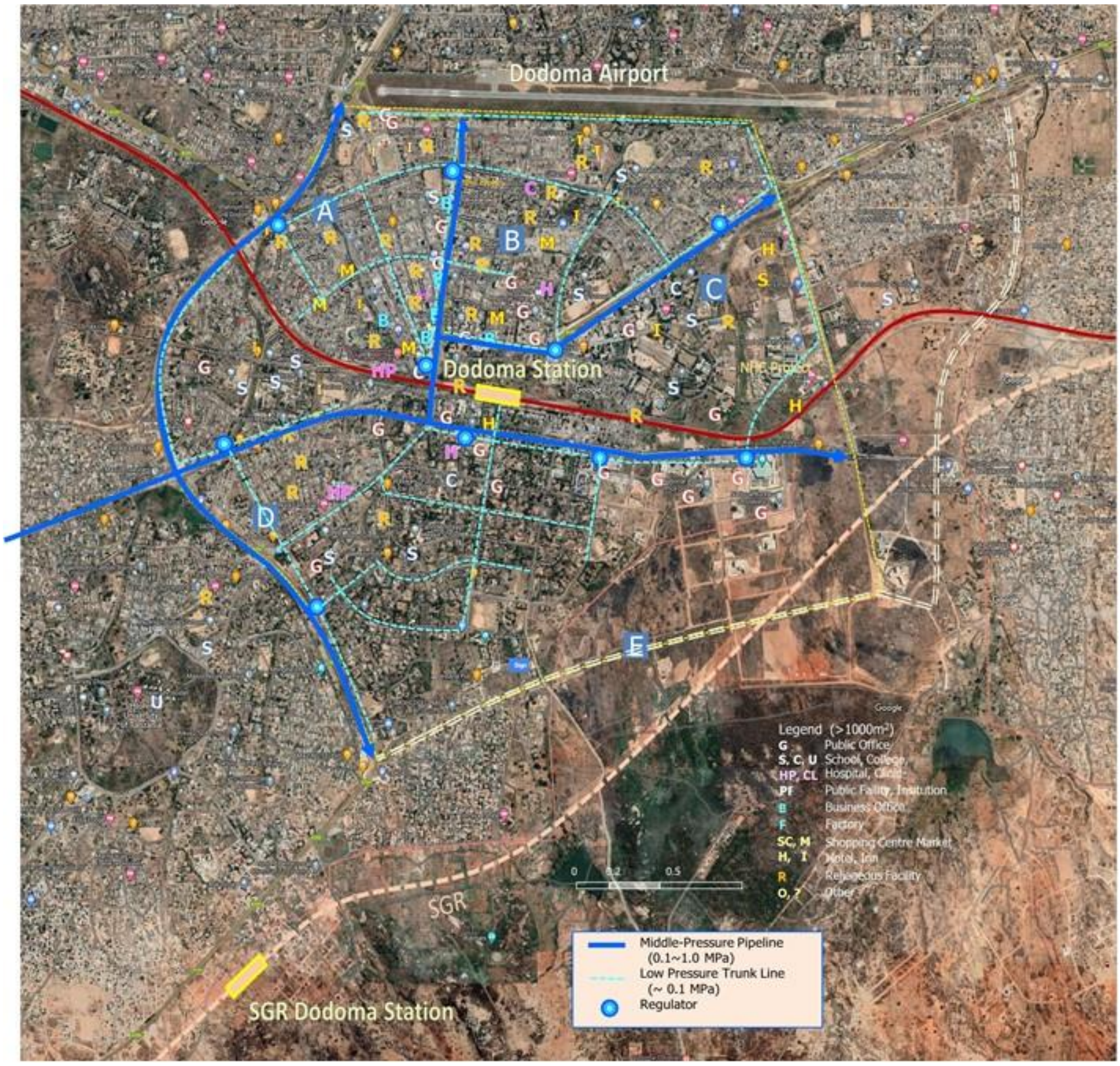
10.5.2 City Gas Plan-B: Central Business District at City Centre

In City Gas Plan-B as shown in Figure 10.5-4, the LNG satellite receiving terminal B will be built next to the Zuzu power station located 5 km west of the Dodoma city centre. As the phase-1 of the gasification project, city gas will be supplied to the Central Business District from the terminal. The LNG satellite receiving terminal can be installed near the supply area, but this location is selected with an expectation that the Zuzu power plant can be converted from diesel oil to natural gas as well as the proximity to the Kisota Industrial Area. This location is close to the railway with an unused passage of service line. If the gas conversion of the Zuzu power plant is realized, it will be possible to transport the LNG containers by rail. In that case, it will also be possible to transfer containers to the LNG satellite receiving terminal A and C from here by trailers.



Source: JICA Study Team – work on Google Map

Figure 10.5-4 City Gas Plan B: Dodoma City Centre



Source: JICA Study Team – work on Google Map

Figure 10.5-5 Central Business District of Dodoma

The medium-pressure pipeline is installed about 5 km from the LNG satellite receiving terminal B to the supply area and about 10 km along the main road (Route A104, B129 and Kikuyu Avenue). As there is no detail section map like City Gas Plan A, the pipeline plan is drafted using the Google map. In total, 110 km low-pressure pipelines will be laid down along the entire road in the supply area of about 1,000 hectares. In addition, regulators should be installed one for every 1 km^2 of the supply area. Also, the paving cost[70] is calculated considering that the paved road ratio in the object area including access paths to houses is 50% reading from the Google photo-map. Under these assumptions, the estimated construction cost of the city gas system for City Gas

[70] Paving of the road is assumed to be partial pavement of 1m width. If overall paving is necessary, the unit cost of pavement will increase.

Plan B is estimated to be approximately $34 million as shown in Table 10.5-2.

(Table 10.5-2 is withheld because of confidential information.)

10.5.3 City Gas Plan-C: Iyumbu Satellite Centre

City Gas Plan-C supplies city gas to the satellite town under construction in Iyumbu located in 12 km southeast of the central area of Dodoma city. Figure 10.5-7 shows an image of pipeline installation plan. As the Iyumbu Satellite Centre will be built in the suburbs open space, there is no need to dig up roads. So, there are fewer construction problems compared to existing urban areas. In this plan, an LNG satellite receiving terminal C will be installed near the Iyumbu satellite centre and city gas will be supplied at medium pressure from the terminal to the town. The city gas is depressurized by regulators installed in the supply area and the city gas is supplied to all areas through low-pressure pipelines. The supply facilities required for the project are 3km medium-pressure pipelines, 11km low-pressure pipelines, and 4 regulators. The construction cost for the supply facilities is estimated to be about $ 4 million as shown in Table 10.5-3. As the town is unpaved, no pavement cost is anticipated.

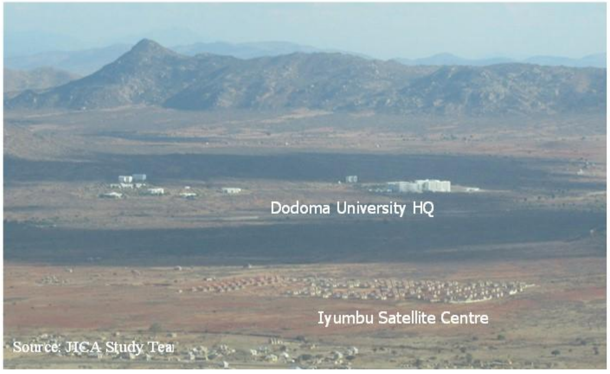
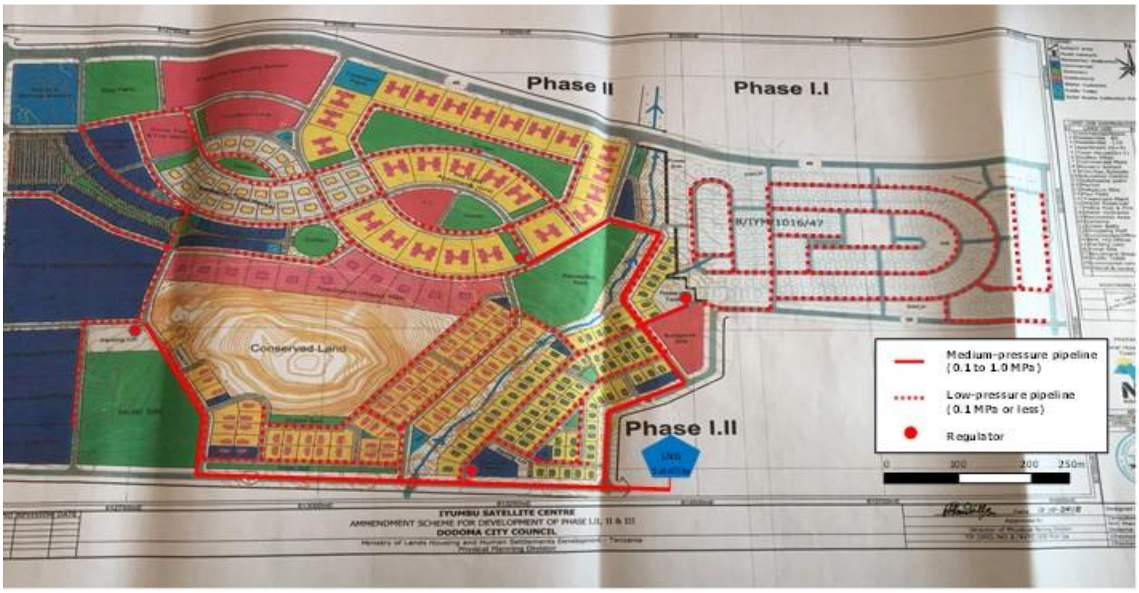


Figure 10.5-6 Iyumbu Satellite Centre

(Table 10.5-3 is withheld because of confidential information.)



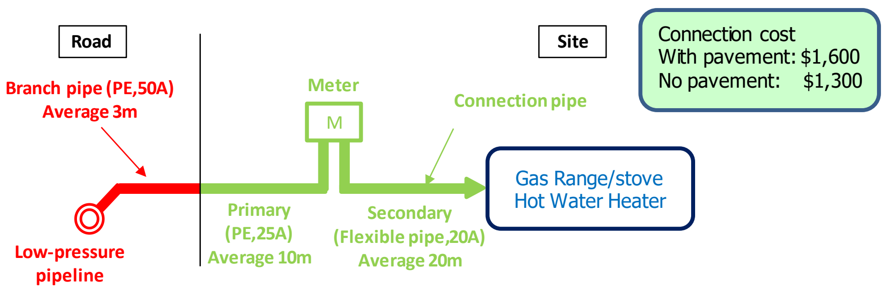
Source: JICA Study Team based on Dodoma City Council

Figure 10.5-7 Image of Pipeline Installation for City Gas Plan-C

10.5.4 Connection Cost

Construction cost of the city gas supply system is examined as above. In order to use the gas, it is necessary to install a branch pipe to the site of the user and connection pipes to the gas equipment as shown in Figure 10.5-8. This cost largely depends on the site size, road conditions (paving, road width, etc.). In this section, an approximate cost is calculated assuming an average condition.

Assuming that the average road width is 6 m, the length of a branch pipe will be 3 m which is a half of the road width. The primary pipe up to the gas meter is assumed to be 10 m and the secondary pipe from the gas meter to the gas equipment is assumed to be 20 m. Based on the above assumptions, the average connection cost for a residential house is calculated to be 1,600 USD with pavement and 1,300 USD without pavement on the road.



Source: JICA Study Team

Figure 10.5-8 Assumptions on Pipe Connection and Cost

(Table 10.5-4 and 10.5-5 are withheld because of confidential information.)

10.5.5 City Gas Sector Cost Summary

The amount of the upfront capital expenditure up to 2030 estimated in the above analyses is summarized in the table below. Construction cost of the city gas network comprises about 2/3 of them. In case the Zuzu power station is switched to gas, the satellite construction cost is inflated for construction of two 3,000 KL tanks and relevant facilities. When CHPs are considered, the storage tank capacity at satellites need to be expanded, while the connection cost remains almost same as only a few connections will be made.

Table 10.5-6 Investment Amount for the City Gas Sector

	Upfront Investment up to 2030					Composition				
	A:NGC	B:City Centre	B: With PS	C: Iyumbu	Total w/o PS	A: NGC	B:City Centre	B: With PS	Iyumbu	Total w/o PS
	$mln	$mln	$mln	$mln	$mln	%	%	%	%	%
Satellite	3.1	3.2	28.0	0.5	6.8	27.3	8.0	43.2	8.5	11.9
with CHP	5.3	4.5		0.7	10.5	46.6	11.2		11.8	18.3
City Gas System	8.0	26.4	26.4	3.9	38.3	70.4	65.9	40.7	66.0	66.8
Connection	0.3	10.4	10.4	1.5	12.2	2.3	26.1	16.1	25.6	21.3
with CHP	0.3	10.5		1.5	12.3	2.8	26.2		25.9	21.5
Total	11.4	40.0	64.8	5.9	57.3	100.0	100.0	100.0	100.0	100.0
with CHP	13.6	41.4		6.1	61.1	119.8	103.3		103.7	106.7

(Note): Figures do not include administration cost during the construction phase.

It is controversial who should pay the connection cost. In Japan, the city gas system is the gas company's asset and the connection pipe the user's asset paid by the user. Connection cost as the upfront investment is not cheap for individual small users such as household. It is necessary to open the door at the potential marginal customer somehow to promote gasification. On the other hand, it is less than 20% of the investment amount of the city gas company and occurs for an extended period of time as gas penetration takes time. Since prospect of city gas business is likely to change greatly pending the policy who pays the connection cost at beginning, it is important to structure the proper business scheme when starting the city gas supply.

10.6 Natural Gas Station for NGVs

Natural gas is used as fuel for driving motor vehicles in the form of CNG (compressed natural gas) and LNG (liquefied natural gas). CNG is popular for NGVs (natural gas vehicles) worldwide. However, as their driving distances are relatively short as shown in Table 10.6-1, CNG vehicles are mainly used for short distance routine services such as commuter vehicles, delivery services and garbage collection. In recent years, LNG has become popular among heavy vehicles such as buses and fleet-trucks for long-distance services where natural gas became cheaper such as in the United States.

Table 10.6-1 Driving Distances of NGVs

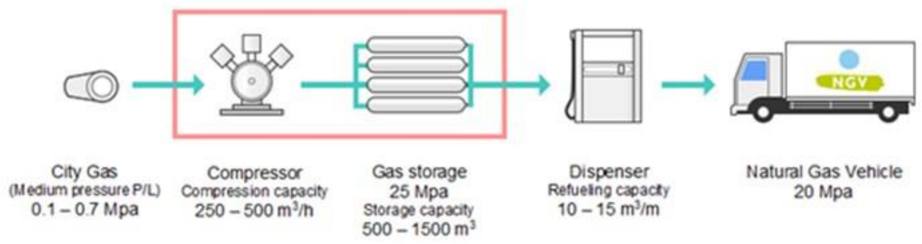
Vehicle type		Three Wheeler	Passenger Car	Light Truck/mini-bus	Heavy duty bus and truck
Fuel Mileage	km/ltr	40 (Gasoline)	10 (Gasoline)	8 (Gasoline)	2 (Diesel)
Fuel Tank (CNG)	ltr	30	120	300	1,000
Refuelling at	80%	24	96	240	800
Drive Distance : CNG	km	225	225	450	330
LNG	km	-	-	-	975

Assumptions: CNG pressure at 20MPa, LNG intensity at 0.43

CNG can be supplied from city gas as well as LNG (L-CNG as explained later). LNG can also be supplied from city gas, but it requires liquefaction facility to be installed at the service station. In case of Tanzania, LNG may be supplied from dedicated LNG plant(s), which also allows supply of CNG at the service station with a relatively small amount of additional investment.

10.6.1 Conventional CNG Station

A natural gas filling station to serve for CNG vehicles, typically supplies gas provided from medium pressure city gas pipelines at a pressure of 0.1 – 0.7 MPa. Gas is compressed at the station up to 25 MPa, stored in gas storage tubes as CNG and supplied to NGVs through a dispenser. Except for the high pressure section, the system is similar to a regular petrol station.



Source: The Japan Gas Association

Figure 10.6-1 Conventional CNG Station by City Gas

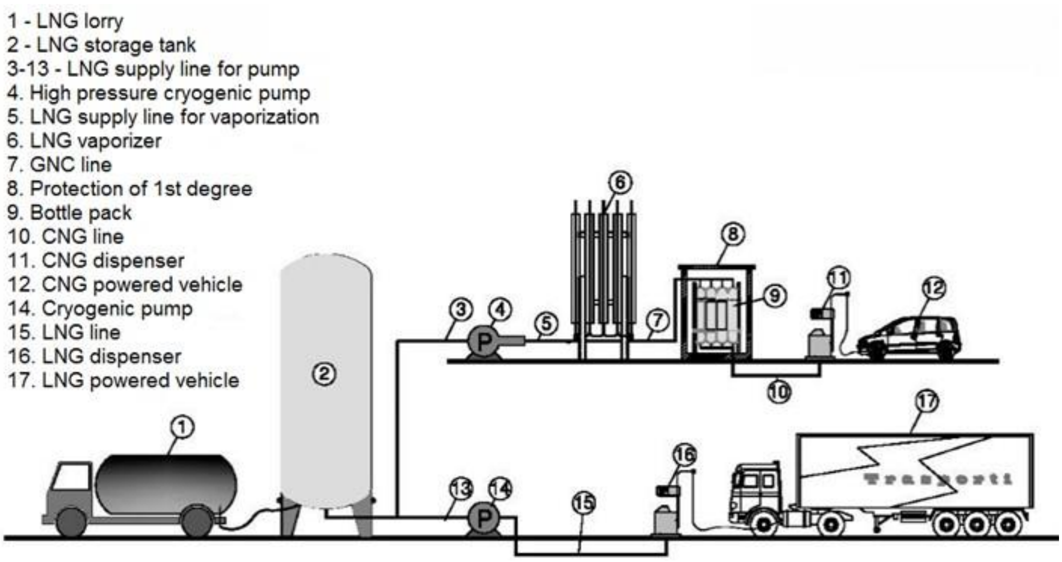
Source: Yokota Oil, http://www.yokota-oil.co.jp/service/ecost.html

Figure 10.6-2 Petrol Station with CNG (ECO Station)

10.6.2 L-CNG Station

Configuration of an L-CNG system is shown in Figure 10.6-3. It receives LNG from an LNG lorry into an LNG storage tank, send it with an LNG pump, vaporizes it and put odours in it, adjust pressures to produce CNG, and store it in high pressure tubes before refuelling. An L-CNG system makes it possible to install CNG stations in the areas without any gas pipeline. Compared to conventional CNG Stations, L-CNG system uses an LNG booster pump instead of a compressor to obtain a high pressure. This reduces electricity costs by 1/10. This is because the volume factor of LNG is extremely high (580-590 times in volume when vaporized).

An L-CNG system can supply CNG for passenger cars, light duty vehicles and public transport vehicles. It can also supply LNG directly for heavy duty vehicles.



Source: Gi Enne Elle, http://giennelle.com/impianti/

Figure 10.6-3 L-CNG and LNG Station

Site area	2,536 m^3	
	Petrol and Diesel	CNG
Dispenser	Diesel: 8	CNG: 2
	Gasoline: 2	
Fuel tank	Diesel: 104,000 L	LNG: 40,000 L
	Regular gasoline: 10,000 L	
	Premium gasoline: 6,000 L	
Other equipment	-	Pressurizer, Humidifier, Vaporizer,
		BOG tank, Gas storage, Gas compressor

Source: Japan Motor Terminal Co., Ltd.

Figure 10.6-4 L-CNG Station in Japan

10.6.3 Construction Cost of CNG Station

10.6.4 Cost Estimation for Natural Gas Service Station

(These sections are withheld because of confidential information.)

10.6.5 CNG Conversion in India

Many used cars are imported in Tanzania which are designed to use petrol or gasoline. To use natural gas instead, it is necessary to convert their fuel-engine system. Conversion of a gasoline driven engines are relatively easy. On the other hand, diesel engines are expensive to convert as natural gas does not automatically ignite even when highly pressurized and hence deep refurbishment is necessary. Examples in India are cited below where natural gas conversion is very popular.

1) Passenger Cars

Gasoline-powered vehicles are easily converted to NGVs. Various types of CNG conversion kits are manufactured in India as well as imported from Italy. The following figure shows an example of CNG Conversion Kit and installed CNG tanks.

Source; Lovato, Italy and Indiamart

Figure 10.6-8 Example of CNG Conversion Kit and installed CNG tank

The following table shows the example of current CNG conversion cost in India. As for CNG cylinders, there are many CNG cylinder suppliers in India.

Table 10.6-9 Example of CNG Kit Cost (in US$)

Type	Hatchback	Sedan	SUV's
CNG Kit	154 - 230	230 - 307	307 - 384
Installation of CNG Kit	8 - 15	8 - 15	8 - 15
CNG Kit Repair	8 - 15	8 - 15	8 - 15

Note; Original unit is Rupee. Exchange rate at 65.1 Rupee/ US$

Source; bro4u

2) Diesel Vehicles

The following figures show an example of Diesel to CNG Conversion and an image of Bus CNG Kit installation.

Source; Indiamart

Figure 10.6-9 Example of Diesel to CNG conversion

Information is limited on the cost of diesel bus conversion into CNG. An article on THE TIMES

OF INDIA, "Nagpur Municipal Corporation to convert 50 diesel buses into diesel bus"[71], reports on diesel to CNG conversion of a bus as follows:

a. Ace Gas Conversion Company

- "A diesel-to-CNG conversion kit could cost anywhere between Rs 60,000 ($922) to Rs 1 lakh ($1,536), compared to Rs 40,000 ($614) for petrol engines.
- For converting a diesel bus to CNG, an expenditure of Rs 13.50 lakh ($20,737) and for Midi bus Rs 9.50 lakh ($14,593) was estimated."

b. Rawmatt Industries (Fuel dispenser and CNG Kit trader)

- "The cost of installing the kit: between Rs 3 lakh ($4,608) and Rs 3.25 lakh ($4,992) on its own."

Rawmatt Industries was selected by Nagpur Municipal Corporation to convert 50 diesel busses into CNG. Although no firm information is available, we may consider the gas conversion cost including technical fee will be $1,000 per light vehicle and $15,000 – 20,000 per heavy vehicle.

10.6.6 Conversion Cost and Competitiveness

From the above information, we can calculate the relationship of the conversion cost and effect of fuel price discount as shown in Table 10.6-6.

Table 10.6-10 Gas Conversion Cost and Fuel Price Discount

		unit	Tricycle Taxi	Passenger cars	Light trucks/ mini-buses	Heavy Duty Vehicles	Heavy Duty Long Range
Driving distance							
Daily		km	200	50	100	100	300
Annual	330 days	km	66,000	16,500	33,000	33,000	99,000
Fuel Milage							
Gasoline	8,000 kcal/ltr	km/ltr	40.00	10.00	8.00		
Diesel	9,100 kcal/ltr	km/ltr			8.80	2.00	2.00
Annual Fuel Consumption	Gasoline	litre	1,650	1,650	4,125		
	Diesel	litre			3,750	16,500	49,500
			$/year	$/year	$/year	$/year	$/year
Annual Cost Saving	0.10	$/litre	165.0	165.0	412.5	1,650	4,950
	0.20	$/litre	330.0	330.0	825.0	3,300	9,900
Repayment							
Gasoline Vehicle	Conversion Cost		years	years	years	years	years
at 10 cents/litre discount	1000	US$	6.1	6.1	2.4		
	2000	US$	12.1	12.1	4.8		
at 20 cents/litre discount	1000	US$	3.0	3.0	1.2		
	2000	US$	6.1	6.1	2.4		
Diesel Vehicle	Conversion Cost						
at 10 cent discount	10000	US$			24.2	6.1	2.0
	15000	US$			36.4	9.1	3.0
at 20 cents discount	10000	US$			12.1	3.0	1.0
	15000	US$			18.2	4.5	1.5

Source: JICA Study Team

71 https://timesofindia.indiatimes.com/city/nagpur/nmc-to-convert-50-diesel-buses-into-cng/articleshow/66529645.cms

For gasoline driven vehicles, conversion cost will be in the range of $1,000-2,000. If the fuel price discount is 20 cents per litre, the upfront investment will be paid back in 3-6 years. For diesel driven vehicles, conversion cost is expensive in the range of $10,000-15,000. However, as large vehicles consume large amount of fuel, such cost can be paid back within 5 years. If natural gas is competitive with imported petroleum products at a margin greater than 20 cents per litre, introduction of NGVs will become an attractive option. At the same time, however, reduction in import duty will be a more effective policy as the vehicle users would not incur upfront investment. Such fund may be recovered later by a levy on the natural gas sold as fuel for NGVs.

Chapter 11 Economics of Domestic Gas Supply System

In this chapter, we examine economics of the mini-LNG based virtual pipeline plan by its sub-sector. As discussed below, most of the sub-sectors are commercially viable. However, economics is questionable for the city gas sector if only small energy users such as office buildings and households are aggregated. Unless intensive gas users such as CHPs are not considered, different approaches are necessary to consider the city gas sector such as from the view point of improving quality of life and developing environmentally friendly energy structure.

11.1 Model Project

Based on the investigation in the foregoing chapters, the model project for evaluation of project economics and its derivative cases are set out as follows;

a. *LNG Plant*

a) A mini-LNG plant will be constructed at the Kinyerezi energy complex. It obtains the feedgas from the existing GASCO plant there.
b) The LNG plant will have 2 trains of 200 tons per day liquefaction capacity, with one additional train as future plan.
c) As demand increases, additional train may be constructed at the Kinyerezi site. Beyond this capacity, additional supply will be sought from the new large-scale LNG plants to be constructed in Lindi.

b. *LNG Transport*

a) LNG will be transported to destinations by trailer-containers with net payload of 18 tons each.
b) LNG will be delivered by bulk transport to the city gas systems in Dodoma, large industrial users and gas service stations in the north-eastern regions.

c. *LNG Users*

a) Large industry users to receive LNG by direct bulk transport located elsewhere in Morogoro, Dodoma, Tanga, Moshi and Arusha
b) City Gas Company at Dodoma
c) Gas service stations (see item *e*)
d) Zuzu Power Station (see item *f*)

d. *Dodoma City Gas Company*

a) Plan-A with Satellite-A at the New Government City
b) Plan-B with Satellite-B next to the Zuzu power station for gas supply to the Dodoma city centre area
c) Plan-C with Satellite-C at the Iyumbu Satellite Centre
d) As an optional case, CHP (combined heat and power) will be adopted at large buildings and commercial facilities.

e. Gas service stations

a) Total five (5) Gas service stations will be put in operation in 2025

b) Two (2) will be built at Satellite-A and Satellite-B

c) Three (3) will be built between Dar es Salaam and Dodoma

d) More service stations will be built under an accelerated NGV promotion program

f. Zuzu Power Station

a) Next to the Satellite-B, the existing diesel driven Zuzu power station will be replaced with a natural gas driven power plant.

b) The plant capacity will be 50 MW x 2 power generators.

In order to justify the project, there should be reliable gas sources and stable gas demands. The total feed gas requirement for 25 years of the project is about 160 Bcf for the 200t/d x 2 trains plant. Therefore, gas supply is not worrisome.

On the other hand, present energy consumption in Tanzania is small and the demand presumable for switching to natural gas is limited. Therefore, in addition to soliciting the existing energy users, new demand for the project must be created simultaneously. This requires an ambitious policy decision.

Table 11.1-1 Prospective Gas Demand for Case Study

		2025	2030	2040	2050	2025	2030	2040	2050
City Gas		(in LNG tons)							
Plan-A NGC	Office Building	500	1,000	1,100	1,200	1.6%	1.6%	1.5%	1.6%
	Commercial Facility	1,500	3,400	5,930	10,300	4.8%	4.9%	5.0%	5.1%
	Household	50	100	200	300	0.2%	0.2%	0.2%	0.2%
	Total	2,050	4,500	7,200	11,800	6.6%	6.6%	6.7%	6.9%
Plan-B City Centre	Office Building	500	1,000	1,200	1,470	1.6%	1.6%	1.5%	1.6%
	Commercial Facility	1,500	3,000	5,200	8,720	4.8%	4.7%	4.6%	4.7%
	Household	1,500	3,000	5,200	8,710	4.8%	4.7%	4.6%	4.7%
	Total	3,500	7,000	11,600	18,900	11.3%	10.9%	10.8%	10.9%
Plan-C Iyumbu	Office Building	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Commercial Facility	200	500	600	740	0.6%	0.7%	0.7%	0.7%
	Household	200	500	600	730	0.6%	0.7%	0.7%	0.7%
	Total	400	1,000	1,200	1,470	1.3%	1.4%	1.4%	1.5%
City Gas Total		5,950	12,500	20,000	32,170	19.2%	18.9%	18.8%	19.3%
Direct Delivery		15,000	20,000	32,700	53,200	48.3%	41.6%	37.4%	35.1%
NGV (First 5 Stations)		10,100	28,800	36,500	37,000	32.5%	39.5%	43.8%	45.6%
Total Base Demand		**31,050**	**61,300**	**89,200**	**122,370**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
(Daily consumption:330days/year)		*94*	*186*	*270*	*371*				
Options									
Zuzu Power Station		31,600	63,200	63,200	63,200	101.8%	98.6%	97.3%	98.6%
CHP	NGC	10,000	20,000	22,090	24,400	32.2%	31.2%	30.8%	31.2%
	City Centre	4,000	9,000	9,940	10,980	12.9%	13.0%	13.2%	13.7%
	Iyumbu	600	1,500	1,500	1,500	1.9%	2.0%	2.1%	2.2%
	CHP Total	14,600	30,500	33,530	36,880	47.0%	46.2%	46.1%	47.1%
Accelerated NGV Penetration		0	48,900	106,200	111,000	0.0%	79.8%	119.1%	90.7%

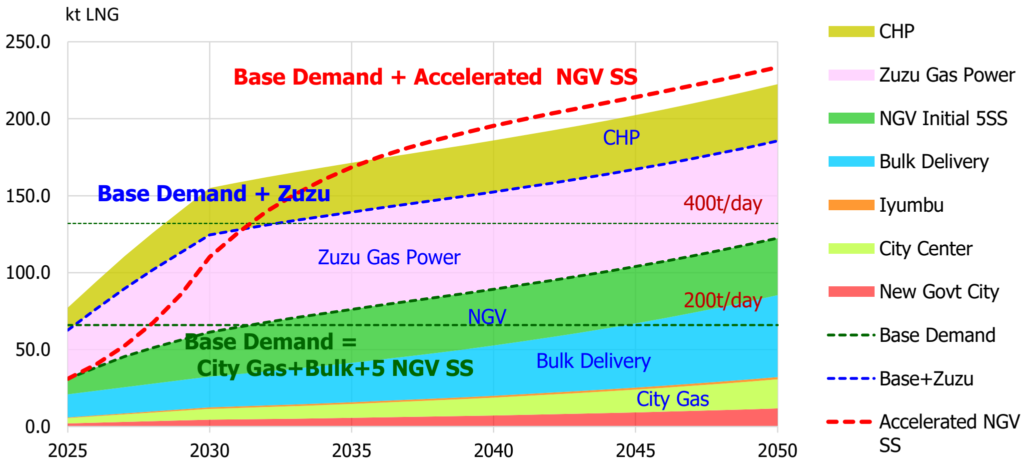
Source: JICA Study Team

Natural gas demand outlook by sector assessed in Chapter 7 is summarised in Table 11.1-1 and Figure 11.1-1. Based on this projection, we examine two demand scenarios in this study.

Base Demand: the aggregate amount of the gas consumption at city gas networks in Dodoma, large industry users and gas service stations

High Demand: Base Demand plus Zuzu Power Station

Gas demand under the *Base Demand Scenario* is relatively small; the daily consumption reaches 200 tons per day only in 2032 but does not exceed 400 tons per day before 2050. Among them, direct bulk delivery for large energy users provides 1/3 of the total demand. However, it is yet a hypothetical scenario and intentions of these potential users must be confirmed in due course. Gas demand for NGVs is also hypothetical and proactive policy decision is necessary to see materialization of such demand. City gas demand remains less than 20% throughout the project period. Gas demand of ordinary office buildings, commercial facilities and households are relatively small. In addition, minor consumers such as households, small shops and restaurants may be sceptical in the early stage and need time to make move toward gasification.



Source: JICA Study Team

Figure 11.1-1 Gas Demand Scenarios

On top of the Base Demand, additional gas demand may be sought from following sectors;

a. Gas switching of the Zuzu power station.
b. CHP (combined heat and power) to be adopted at new building and regional energy supply systems.
c. Accelerated introduction of NGVs.
d. Additional industrial users located or emerging elsewhere in the country.

For the *High Demand Scenario*, we pick up an addition of the Zuzu power station gas switching as an example. This will push up the utilization of the LNG plant from 60% to 93% and reduces the plant toll significantly as discussed later. Similar effect may be expected from accelerated NGV promotion.

To finalise the implementation plan, it is foremost important to identify if large prospective demand as above would materialise or not. To this end, following issues need to be reviewed:

a. If retrofitting of the obsolete Zuzu power station using expensive imported fuel would be justifiable from the overall view point of the national electricity plan, or not. If so, when will it occur?

b. If CHP (combined heat and power) could be adopted at the new buildings and/or as regional energy supply systems in comparison with the electricity price available from the grid, or not. If the market electricity price is low, CHP would not be viable despite its high efficiency.
c. What will be the realistic NGV introduction plan? How fast will NGVs be introduced?
d. If existing large users elsewhere in the country are interested in switching to indigenous natural gas? Is there any new industry users coming up?

Upon confirmation of the positive intentions of these stakeholders, the base plan for the city gas development will be established with higher confidence, which will then be used for soliciting herds of minor energy users.

11.2 Business Formation

As discussed in Chapter 10, the LNG based gas supply system may be divided into three sectors, the LNG supply company in Dar es Salaam, the city gas company in Dodoma and natural gas service stations. Their features and tasks are as discussed below.

To start-up these businesses, basic principles and business structure should be set out in each sector on the following issues:

a. Prospect of demand and sales that will define the project size.
b. Participating parties as investors and their roles and responsibilities.
c. Preparation of technology and workforce necessary for the business
d. Funding structure and sources of funds
e. Site acquisition
f. Any other matter specific to the business

In addition, relevant policies, laws and regulations for promotion of these businesses should be prepared.

Once these elements are all set, the final investment decision (FID) will be made. In case to seek for institutional finance from international financing agencies, a thorough feasibility study is required that qualifies the standard international financing criteria and verifies that the project is “bankable.”

11.2.1 LNG Supply Company

The main tasks of the LNG Supply Company include:

a. Purchase of feedgas from GASCO or other gas supplier(s)
b. Liquefaction, storage and shipping of LNG at Kinyerezi
c. Transport and delivery of LNG to larger users, local gas distributors and natural gas service stations

d. Marketing of LNG to these LNG customers

A sufficient amount of feedgas is available at the Kinyerezi gas terminal. Therefore, major issues for formulation of the company may be as discussed below.

Securing enough amount of credible demand is foremost important to establish the project. For marketing of LNG, appropriate pricing principles and proper sales conditions must be established for different categories of customers, namely, a variety of direct bulk users, the city gas companies and natural gas service stations. It further requires investigation on prospects of the city gas markets and NGV promotion programs. It is an important precondition that the LNG is competitive with other energies with a comfortable margin while the commerciality of the project is assured. The latter heavily depends on the demand size and its development profile. In view that LNG is a capital-intensive business and requires high upfront investment, favourable policy actions will help promote early development of the project.

The mini-LNG based virtual pipeline system uses proven technologies in its all aspects. However, in view that it handles extremely low temperature and high pressure, the project operation may be started led by experienced expatriate engineers. Fresh national operators must go through sufficient education and training in advance of the production operation.

Transport of LNG requires more than 50 trailer-containers and more than 100 drivers. Same as the plant operators, the truck drivers must go through appropriate education and training on handling of LNG. In view of the specific routine of truck operation and maintenance, the sector may be separated from the LNG Supply Company and out-sourced. In this case, the transport section of the Company is still needed to coordinate shipping schedule and overall transport operation. ICT must be fully adopted linking customers and terminals to optimize the production, delivery and inventory management.

11.2.2 City Gas Company

The main tasks of the Dodoma City Gas Company include:

a. Purchase of LNG as feedstock
b. Storage, regasification and gas distribution at Satellite-A, B and C for their networks
c. Development, monitoring and repair of the gas distribution pipeline and relevant facilities
d. Marketing of city gas (and LNG)
e. Customer response at inquiries and accidents

The company specializes in marketing and delivery of gas in Dodoma and the vicinity operating three satellite terminals. LNG will be purchased from the LNG Supply Company on delivered basis. Satellite-B is the biggest facility to serve the Dodoma city centre area, Kisota industrial area, and, if appropriate, the Zuzu power station. It will be operated 24 hours a day with three shifts. Satellite-A will be operated on one shift a day basis, while Satellite-C will be unmanned and operators from Satellite-B will attend only at the time of unloading. Plant operators must go through appropriate education and training well in advance.

To respond to any incident immediately, a technician team must stand-by 24 hours a day. The team members must hold qualification on safe gas operation through education and training.

Pipe connection to users is time consuming work; to dig a ditch, lay down and connect the pipe and flow meter and backfill. Quite a number of skilled worker teams will be necessary. If one team completes two connections a day, 10 teams are necessary to connect 5,000 users in a year. This job is likely to be out-sourced. However, it is necessary to create such service companies well in advance.

At the outset, three satellites are not connected by pipeline but are operated independently. As the city gas system expands outward from the phase-1 project coverage, service areas may become closer and they will eventually be connected by pipeline. City gas business is capital-intensive, but its demand builds up only gradually. Greater volume of the base demand and faster development of the demand are the key for its project economics. Supporting policies may be considered from this view point.

11.2.3 Natural gas service stations

The main tasks of the NGV service stations include:

a. Purchase of LNG as feedstock
b. Receiving, storage and regasification of LNG and gas supply for natural gas vehicles (NGVs)
c. Technical and maintenance services for NGVs

To create the business, natural gas vehicles must be introduced. A comprehensive transport policy must be established to this end.

Business at a natural gas service station will be similar to a regular petrol station except that it should handle LNG at extremely low temperature (-162 degree C) and CNG at extremely high pressure (25 MPa). With appropriate education and training, operators must hold knowledge and qualification for handling these materials. Service stations may also be expected to provide technical and maintenance services for natural gas vehicles.

Natural gas service stations should be developed as a network or a chain to serve vehicles to drive as freely and longer as possible. To this end, they should be developed according to a comprehensive long term network plan.

In addition, natural gas service stations may also be able to serve as terminals for community gas and electricity distribution system to promote rural electrification.

11.3 Economics of the Project

11.3.1 Cost Estimation

Incorporating the discussion in Chapter 9, the investment amount up to 2030 for the Base Demand Scenario is compiled in Table 11.3-1, which assumes gas supply for city gas at three locations in Dodoma, large industrial users for direct bulk transport and five (5) Gas service stations. Most of the investment occurs before start of production. However, some amounts will be incurred even after the start-up as transport vehicles are procured and users are connected additionally as the demand grows. Accordingly, the second storage tank at Satellite-B will be built later. As the usable life of the vehicles is limited, assumed at 10 years for a trailer-head and 20 years for a container/chassis, replacement of these vehicles occurs from middle points of the 25 year project period.

The construction cost of the mini-LNG plant is biggest among the cost items and amounts to 2/3 of the total cost. The second biggest cost item is the construction cost of the city gas network. It should be noted that the city gas construction cost is incurred only for city gas users, while the LNG plant cost is shared by all sectors. Considering that only 20% of the LNG is supplied for the city gas, and thus the 20% of the plant cost or $29.5 million is allocated for the city gas sector, construction cost of the city gas system at $42 million is significantly larger.

For Satellite-B located at Zuzu, the storage tank capacity is assumed to be 400 KL x 2 for the Base Demand case. However, if Zuzu power station gas switching would be considered, it should be ramped up to 3,000 KL x 2. This will push up the total investment by more than 10%.

Table 11.3-1 Summary of Investment Amount

Stage	Preperation			Construction			Upfront	Production	Total	
Year	2019	2020	2021	2022	2023	2024	Total	-->2030	up to 2030	
	$ million	$ million	$ million	$ million	$ million	$ million	$ million	$ million	$ million	%
LNG Plant (200t/d x 2 trains)										
Feasibility Study	1.0						1.0		1.0	0.4
Marketing	0.3	0.3	0.3	0.3	0.3	0.3	1.8		1.8	0.7
Construction				15.0	50.0	75.0	140.0		140.0	56.3
Administration	0.8	0.8	0.8	0.8	0.8	0.8	4.8		4.8	1.9
Total	2.1	1.1	1.1	16.1	51.1	76.1	147.6		147.6	59.4
Transport										
Vehicles						1.4	1.4	8.6	9.9	4.0
Administration					0.3	0.3	0.5		0.5	0.2
Total					0.3	1.6	1.9	8.6	10.4	4.2
Satellite (A+B+C) without Zuzu Power station										
Construction				1.7	4.7	9.5	15.9	2.9	18.8	7.6
Administration				0.1	0.1	0.1	0.3		0.3	0.1
Total				1.8	4.8	9.6	16.2	2.9	19.1	7.7
City Gas Network (A:NGC+B:CBD+C:Iyumbu)										
Construction				0.5	13.0	38.6	52.1		52.1	21.0
Administration				0.9	1.5	2.9	5.3		5.3	2.1
Total				1.4	14.5	41.5	57.4		57.4	23.1
Connection Cost						6.4	6.4	7.6	14.0	5.6
LNG Supply Company	2.1	1.1	1.1	16.1	51.4	77.7	149.5	8.6	158.0	63.6
City Gas company	0.0	0.0	0.0	3.2	19.3	57.5	80.0	10.5	90.5	36.4
Total	2.1	1.1	1.1	19.3	70.7	135.2	229.5	19.1	248.5	100.0
Satellite (A+B+C)										
with Zuzu Power Plant				3.7	8.6	17.2	29.5	7.5	37.0	14.9

Most of the investment occurs two years prior to the production start. A major alternative option against the above scenario will be replacement of the power source at the LNG plant from the gas engine generator to electricity purchase from the grid. The next option will be use of railway service for transport. Both of these options may reduce the investment amount of the project, while the overall cost comparison must be made carefully to examine their benefit.

11.3.2 Estimated Toll and Gas Price in Dodoma

Incorporating the above estimation on the investment amount and other cost assumptions discussed in Chapter 9, project economics are calculated to estimate the toll required at each sector to satisfy an IRR of 10% for the project period of 25 years after start of operation. Starting with the feedgas price of $5.36/MMBtu obtained from the GASCO system, *estimated gas prices at each delivery point in Dodoma* are summarized as below.

1. Ex-satellite Gas Price

The ex-satellite gas price is estimated as shown in Table 11.3-2. It is the aggregate amount of the feedgas price and necessary tolls for liquefaction, transportation, storage and re-gasification. The transportation cost is slightly different from those in Table 10.4-1 as demand scenarios are different.

For the Base Demand Scenario to supply gas for city gas in Dodoma, bulk delivery for industrial users and five (5) Gas service stations, the average ex-satellite price in Dodoma is calculated to be $20.19/MMBtu. This mainly comprises the feedgas price and liquefaction cost.

Table 11.3-2 Cost by Sector and Ex-Satellite Gas Price in Dodoma

Sector	Base Demand		High Demand	
	City Gas+Bulk+NGV 5 SS		plus Zuzu PS	
	$/MMBtu	%	$/MMBtu	%
Feedgas Price	5.36	26.5	5.36	37.0
LNG Plant	**9.89**	49.0	**5.89**	40.7
Transport for Dodoma by container	1.79	8.9	1.69	11.7
Satellite Terminal	3.15	15.6	1.54	10.6
Ex-Satellite in Dodoma	**20.19**	100.0	**14.48**	100.0
	$/ton		$/ton	
Oil 10,000 kcal/kg	801		575	
	t/day	%	t/day	%
Average LNG production (plant utilisation)	242	**60.5**	372	**93.1**

Source: JICA Study Team

If gas switching of the Zuzu power station is considered, as an example of High Demand Scenario, it reduces to $14.48/MMBtu. This difference is brought mainly by dilution of the LNG plant cost, which is derived from higher utilisation of the plant. For the LNG plant with two (2) trains of 200 tons per day production capacity, the average operation rate for the entire project period remains at 60.5% for the Base Demand scenario. However, it goes up to 93% for the High Demand scenario. The higher demand may be brought not only by the Zuzu power station gas switching but also by increasing industrial users and accelerated introduction of NGV stations.

Ex-satellite gas prices for these scenarios will be $600-800 per ton oil equivalent and likely be competitive with imported petroleum products.

2. City Gas Price

Starting with the above ex-satellite gas price, an average city gas delivered price in Dodoma is estimated as shown in Table 11.3-3. For the Base Demand scenario, the average city gas toll is calculated to be $21.00/MMBtu including connection cost. This extremely high cost is required as only minor users are considered in this scenario. If large gas consumption projects such as CHPs are introduced, it dramatically reduces to $7.46/MMBtu.

The outcome suggests that it is difficult to construct a city gas system as a commercial business without certain core users such as large industries to provide the anchor demand. Nevertheless, city gas supply may need to be considered as a measure to improve quality of life and save environment. This matter will be further discussed later.

Table 11.3-3 City Gas Delivered Price

Sector		Base Demand				High Demand			
		Ordinary City Gas		plus CHP		Ordinary City Gas		plus CHP	
		$/MMBtu	%	$/MMBtu	%	$/MMBtu	%	$/MMBtu	%
Ex-satellite Price		**20.19**	49.0	20.19	73.0	14.48	35.2	**14.48**	66.0
City Gas		**21.00**	51.0	**7.46**	27.0	21.00	51.0	**7.46**	34.0
City Gas Network		18.47	44.8	6.63	24.0	18.47	44.8	6.63	30.2
Connection		2.53	6.1	0.83	3.0	2.53	6.1	0.83	3.8
					0.0				0.0
Delivered at Users		**41.19**	100.0	27.65	100.0	35.48	86.1	**21.94**	100.0
	Current Price			$/ltr				$/ltr	
Oil 10,000 kcal/kg		1.63	$/kg	1.10	$/kg	1.41	$/kg	0.87	$/kg
Diesel 8,600 kcal/ltr	1.00	1.47	$/ltr	0.99	$/ltr	1.27	$/ltr	0.78	$/ltr
LPG 11,300 kcal/kg	1.30	1.85	$/kg	1.24	$/kg	1.59	$/kg	0.98	$/kg
		t/month	%	t/month	%	t/month	%	t/month	%
Average demand for 25 years		931	100	2,609	280	931	100	2,609	280

Source: JICA Study Team

3. Bulk Users and Gas service stations

Gas prices at bulk delivered users and CNG stations are summarised in Table 11.3-4. They include the cost for storage, regasification and supply on top of the delivered LNG price. That is, for bulk transport users it is a burner tip price, and for an L-CNG station, it is a pump price. These prices look highly competitive against imported petroleum products.

Table 11.3-4 Gas Cost at Bulk Users and Gas service stations

Sector		Bulk Users				NGV station			
		Base Demand		High Demand		Base Demand		High Demand	
		$/MMBtu	%	$/MMBtu	%	$/MMBtu	%	$/MMBtu	%
Feedgas Price		5.36	23.2	5.36	28.3	5.36	26.4	5.36	33.1
LNG Plant		9.89	42.9	5.89	31.1	9.89	48.7	5.89	36.4
Transport for Dodoma by container		1.79	7.8	1.69	8.9	1.79	8.8	1.69	10.4
Arrival Price		17.04	73.9	12.94	68.2	17.04	83.9	12.94	79.9
Satellite Cost at Bulk User (30t/month)		6.03	26.1	6.03	31.8				
NGV station Operation Cost						3.26	16.1	3.26	20.1
Total		23.07	100.0	18.97	100.0	20.30	100.0	16.20	100.0
	Current Price	$/ltr		$/ltr		$/ltr		$/ltr	
Oil 10,000 kcal/kg		0.92	$/kg	0.75	$/kg	0.81	$/kg	0.64	$/kg
Petrol 7,900 kcal/ltr	1.08	0.73	$/ltr	0.60	$/ltr	0.64	$/ltr	0.51	$/ltr
Diesel 8,600 kcal/ltr	1.00	0.82	$/ltr	0.68	$/ltr	0.73	$/ltr	0.58	$/ltr
Fuel Oil 9,700 kcal/ltr	0.74	0.89	$/ltr	0.73	$/ltr	na		na	
LPG 11,300 kcal/kg	1.30	1.03	$/kg	0.85	$/kg	na		na	

Note: LPG price was $1.30/kg for a 15kg cylinder in September 2021. Bulk delivered LPG price may be much lower than them.

Source: JICA Study Team

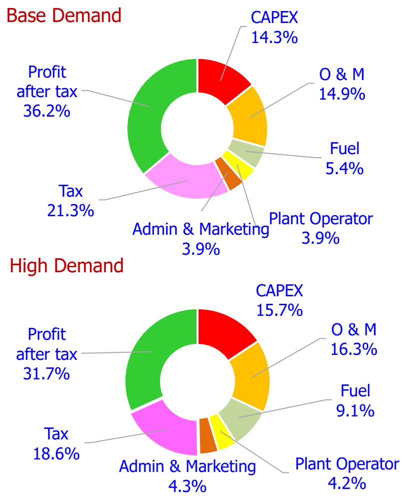
11.4 Sector Analysis

11.4.1 LNG Plant

Figure 11.4-1 shows the cost composition and sensitivity analysis on the mini-LNG plant sector (200t/day x 2 trains) excluding the feedgas cost. Capital cost is assumed to be exempted from the import duty and VAT. Major cost items are the initial capital expenditure, operation and maintenance cost and fuel purchase. As explained in Table 11.3-2, compared with the Base Case, demand is 54% higher for the High Demand case and hence the plant utilization rate improves from 60.5% to 93.1%. This greatly reduces the required toll to satisfy the condition of IRR=10%. Among sensitivity of cost items, impact of a change in CAPEX is greatest, followed by 10 year tax holiday. If we consider a lower project criterion generally applied for utility type projects, 7% IRR with 10 year tax holiday, the required toll will be lowered almost 30%.

Sensitivity Analysis at IRR=10%

Base Demand	Required Toll	
	$/MMBtu	%
Base Scenario	9.89	
10 year tax holiday	8.46	-14.5
20% Reduction in		
CAPEX	8.28	-16.2
OPEX	9.29	-6.0
Fuel Price	9.78	-1.1
IRR=7% with tax holiday	6.82	-31.0
High Demand	**Required Toll**	
	$/MMBtu	%
Base Scenario	5.89	
10 year tax holiday	5.11	-13.2
20% Reduction in		
CAPEX	4.97	-15.6
OPEX	5.55	-5.7
Fuel Price	5.78	-1.8
IRR=7% with tax holiday	4.28	-27.2



Source: JICA Study Team

Figure 11.4-1 LNG Plant: Cost Composition and Sensitivity

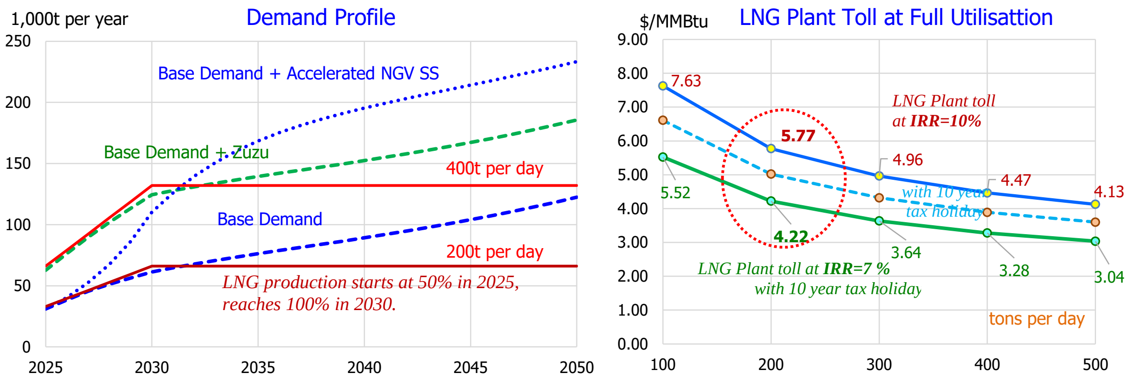
As above, an LNG plant is subject to economies of scale and plant utilisation greatly. Let us consider a Model Demand Profile for a project where plant operation starts at 50% capacity in 2025 and, with demand build up, reaches 100% in 2030, which compares to 94.0% utilization rate for the entire project period of 25 years. Under the Base Demand scenario, demand grows along the development path for a plan of 100 tons per day x 2 trains. If Zuzu power gas switching is included, it goes up closer to a plan for 200 tons per day x 2 trains.

On the other hand, economies of scale work significantly for the plant sector as shown in the right graph of Figure 11.4-2 and Figure 11.4-3. Naturally, large scale plants show better performance. In addition, Figure 11.4-3 suggests:

a. Cost curves are steep in the range of the start demand below 300 tons a day.

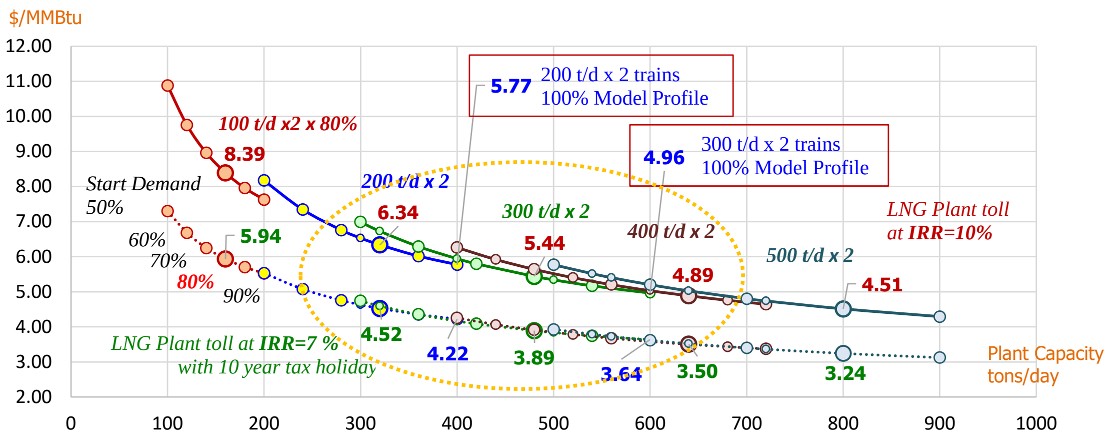
b. Cost curves are overlapping in the higher demand range. This means, to accommodate a same demand, greater plants operated at lower utilisation are beneficial.

Although demand prospect is uncertain, if introduction of NGVs is successful, gas stations may be built more than 5 as assumed for the Base Demand scenario. This may lead to a much higher demand profile. Large industry users may come up in the course of the economic development to push up the demand base. It is better to consider relatively larger plants. Economics of larger plants can be improved by marketing efforts, while such efforts would not work for a smaller plant.



Source: JICA Study Team

Figure 11.4-2 LNG Plant Operation Profile and Plant Toll



Source: JICA Study Team

Figure 11.4-3 LNG Plant Toll by Plant Size and Utilisation

At the same time, effects of policy actions on the capital investment are great in the LNG plant sector. If a proactive policy is taken to provide institutional finance and guarantee, a lower project criterion may become applicable. Applying IRR=7% with 10 year tax holiday, the required will be reduced, for the Model Demand Profile, from $5.77/MMBtu to $4.22/MMBtu for the case of 200 tpd x 2 trains and from $4.96/MMBtu to $3.64/MMBtu for the case of 300 tpd x 2 trains. From these analyses, we may consider a hypothetical mini-LNG plant with a capacity of 200 tons per day times 2 trains and the required toll at $6.00/MMBtu for a commercial case and

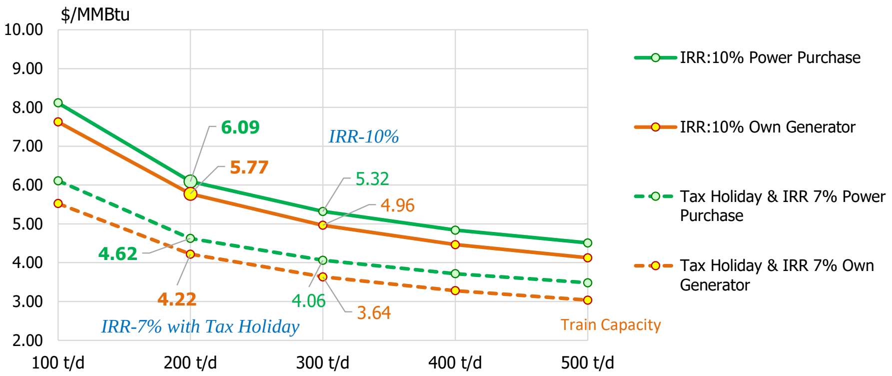
$4.00/MMBtu for a proactive policy case.

Table 11.4-1 examines construction of an additional plant in a later year. Comparison is made on the cases of constructing (A) 300 tpd (tons per day) plant x 2 trains and B) 200 tpd plant x 3 trains; the third train of the latter case will be built 5 years later. Since an additional plant is more expensive as discussed in Chapter 10, Case A is preferable compared with Case B if demand is firm. However, if an additional demand is likely to come up much later, construction plan should be examined carefully.

Table 11.4-1 Additional Plant Construction

Case	A	B	Ref.
	t/day	t/day	t/day
Train Capacity	300	200	200
Trains	2	3	2
Total Capacity	600	600	400
	kt	kt	kt
Sales Volume: 25 years	4,653	4,608	3,102
	$MM	$MM	$MM
CAPEX	195	246	149
Total Expenditure: 25 years including feedgas	1,920	2,005	1,345
Required Toll	$/MMBtu	$/MMBtu	$/MMBtu
IRR=10%	4.96	5.62	5.77
IRR=7% & 10 year Tax Holiday	3.64	4.13	4.22

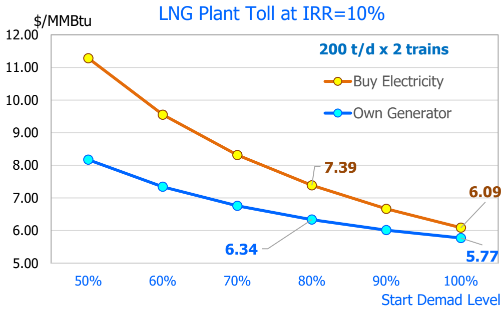
The above LNG plant is designed as a standalone plant with its own gas fired electricity generator to drive compressors. However, as the plant is going to be built at Kinyerezi next to the power plants, an electricity purchase case is examined assuming the TANESCO's electricity tariff for the 11/33 kV class users (capacity charge at Tzs16,550 (US$ 7.2)/kVA per month and energy charge at Tzs 156 (US6.8 cents)/kWh. Fuel consumption is estimated to be equivalent to 10% of the LNG production for the own generator case and 600 kWh per one ton of LNG for the electricity purchase case.



Source: JICA Study Team

Figure 11.4-4 Electricity Purchase versus Own Generator

As the reduction in the upfront investment amount is small for the electricity purchase case (see Table 11.2-3), economics is worse. The total expenditure including feedgas but not tax for the whole project period is $1,449 million for the power purchase case while it is $1,345 million for the own generator case; the former is greater by 7.7%. The average electricity tariff at 7.58 cents per kWh is equivalent to $22.20/MMBtu while the fuel gas cost is at $5.36/MMBtu.



Start Demand	Required Tariff		Electricity (25 years)		
	Own Generator	Buy Electricity	Consumption	Payment	Average Cost
	$/MMBtu	$/MMBtu	GWh	$MM	c/kWh
50%	8.17	11.28	990	86.86	8.77
60%	7.34	9.55	1,188	99.49	8.37
70%	6.76	8.32	1,386	112.10	8.09
80%	6.34	7.39	1,584	124.70	7.87
90%	6.02	6.67	1,782	137.40	7.71
100%	5.77	6.09	1,980	150.00	7.58

Source: JICA Study Team

Figure 11.4-5 Electricity Price and LNG Plant Toll

If TANESCO's electricity supply cost is cheaper than this, electricity purchase will be a beneficial option as the whole energy system pending decision of the equitable electricity price. Power purchase is also advantageous in the following points:

a. Abundant power supply source is available to assure stable and resilient supply.
b. Upfront investment amount will be smaller.
c. Construction, operation and maintenance of the plant will be easier.
d. It creates stable base demand for the TANESCO's plants.

11.4.2 LNG Transport

Transport toll is calculated by destination in Figure 11.4-6, where administration overhead is allocated by sales volume for each destination. In the transport sector, vehicle price and transport distance are the key to decide the necessary toll.

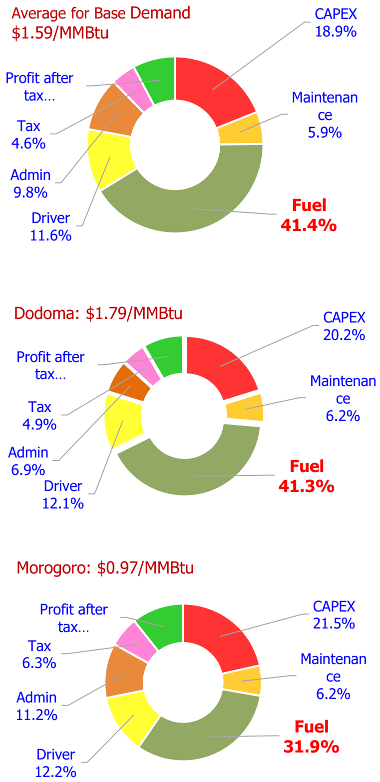
The cost for vehicles is presently subject to import tax and VAT, which in total amounts to 50% of the CIF price of vehicles. Its exemption will reduce the required toll by 9-10% and alleviate the financial burden of truck operators for upfront investment.

Among operating cost items, costs for fuel and the drivers' wage are overwhelmingly large. If the fuel cost is reduced by 20%, the necessary transport toll will be reduced by 6-10%. This may be achieved by switching the truck fuel from imported diesel to CNG or LNG according to the discussion in Section 11.6. Such fuel switching will reduce the sector's cost, foreign currency out-flow as well as GHG emissions significantly. If the total OPEX including drivers' wage and administration cost is reduced by 20%, the toll further goes down by 13-14%. However, costs for imported fuel, drivers' wages and general administration are beyond policy control.

As analysed above, major policy options for the transport sector will be; a) exemption of the import duty on vehicles and b) use of natural gas as truck fuel.

Sensitivity Analysis at IRR=10%

Average	Required Tariff	
	$/MMBtu	%
Base Scenario	1.59	
10 year tax holiday	1.56	-1.7
20% Reduction in		
CAPEX	1.50	-5.8
OPEX	1.36	-14.2
Fuel Price	1.46	-7.9
Import duty exempted	1.43	-9.7
IRR=7% with tax holiday	1.52	-4.5
Dodoma	**Required Toll**	
	$/MMBtu	%
Base Scenario	1.79	
10 year tax holiday	1.76	-1.7
20% Reduction in		
CAPEX	1.74	-2.9
OPEX	1.55	-13.7
Fuel Price	1.65	-8.0
Import duty exempted	1.61	-10.4
IRR=7% with tax holiday	1.71	-4.6
Morogoro	**Required Toll**	
	$/MMBtu	%
Base Scenario	0.97	
10 year tax holiday	0.95	-1.8
20% Reduction in		
CAPEX	0.91	-6.4
OPEX	0.84	-13.6
Fuel Price	0.91	-6.2
Import duty exempted	0.87	-10.7
IRR=7% with tax holiday	0.91	-6.0



Source: JICA Study Team

Figure 11.4-6 LNG Transport: Cost Composition and Sensitivity

11.4.3 City Gas

1. Satellite-A+B+C

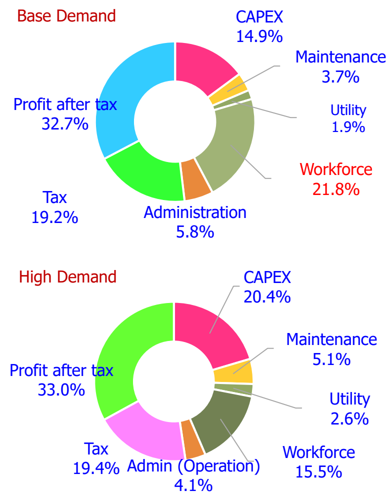
At the satellite terminals, CAPEX and the operators labour cost are the main cost factors. For the Base Demand scenario where only ordinary city gas customers and two (2) Gas service stations are considered, demand size is small and hence the composition of the administration cost (mostly personnel cost) is high. Resultantly required toll is high.

As an example of High Demand case, if CHP is introduced, the upfront investment goes up from $19.1 million to $26.6 million to increase capacity of storage and vaporiser. At the same time, the total gas sale for the entire project period goes up from 555,000 tons to 1,166,000tons. This will significantly dilute the administration cost and the required toll decreases from $3.15/MMBtu to $1.81/MMBtu.

In case the Zuzu power station is added to the customer list, the upfront investment amount goes up from $19.1 million to $37.0 million in order to install large storage tanks. At the same time, the total gas sale for the entire project period goes up from 555,000 tons to 1,720,000 tons. The required toll decreases from $3.15/MMBtu to $1.54/MMBtu but partly offset by the high cost for the large storage tanks.

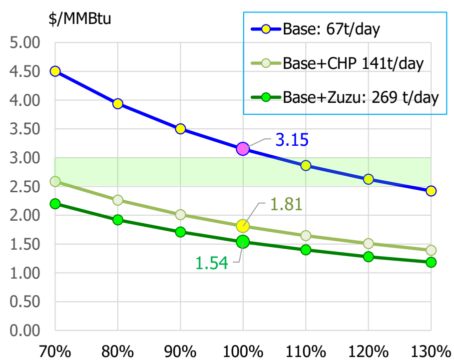
Sensitivity Analysis at IRR=10%

Base Demmand	Required Tariff	
	$/MMBtu	%
Base Scenario	3.15	
10 year tax holiday	2.74	-13.0
20% Reduction in		
CAPEX	2.80	-11.3
OPEX	2.87	-8.7
IRR=7% with tax holiday	2.25	-28.5
High Demand with Zuzu	**Required Tariff**	
	$/MMBtu	%
Base Scenario	1.54	
10 year tax holiday	1.33	-13.5
20% Reduction in		
CAPEX	1.33	-13.6
OPEX	1.44	-6.4
IRR=7% with tax holiday	1.10	-28.4



Source: JICA Study Team

Figure 11.4-7 Satellite A+B+C: Cost Composition and Sensitivity



	Base		Base + CHP		Base + Zuzu	
	t/d	$/MMBtu	t/d	$/MMBtu	t/d	$/MMBtu
70%	47	4.50	99	2.59	188	2.20
80%	54	3.94	113	2.26	215	1.92
90%	61	3.50	127	2.01	242	1.71
100%	67	3.15	141	1.81	269	1.54
110%	74	2.86	155	1.65	295	1.40
120%	81	2.63	170	1.51	322	1.28
130%	87	2.42	184	1.39	349	1.19

Source: JICA Study Team

Figure 11.4-8 Satellite A+B+C Sensitivity by Sales Volume

The required toll changes according to the utilisation rate as shown in Figure 11.4-8. From these calculations we may consider that the satellite terminal cost will be in the range of $2.50-3.00/MMBtu if large scale demand like CHP is not considered.

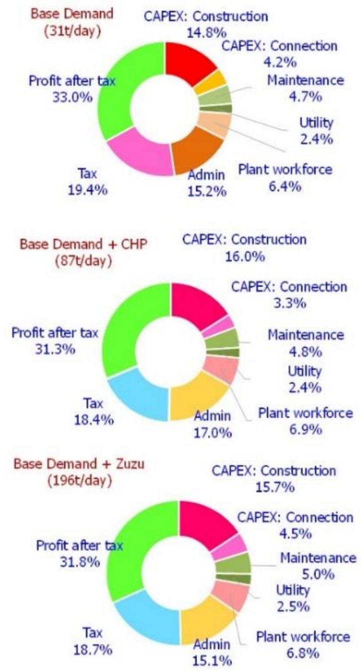
2. City Gas System

In the city gas sector, most of the cost are incurred for gas grid pipe lay-down and administration, while the composition of the connection cost is relatively small. For the Base Demand case where the total city gas demand is limited to relatively minor users, on average 35 tons per day, unit cost for this sector is extremely high to be $21.00/MMBtu.

As an example of high demand case, if CHPs are introduced (or satellites are co-used with industrial estates with similar demand), as shown in Figure11.4-9, the total gas sale of the city gas company for the entire project period increases from 316,000 tons to 824,000 tons by 2.6 times. This will push up the overall revenue greatly and pull down the toll at the city gas sector dramatically to $ 7.46/MMBtu. Market size affects the project economics of city gas significantly. As such it is critically important to secure some core users who provide the anchor demand for a regional city gas system. As personnel cost for operation is relatively high, it should be minimized adopting ICT and digitization technologies.

Sensitivity Analysis at IRR=10%

Base Demand	316 kton	
	$/MMBtu	%
Base Scenario	21.00	
10 year tax holiday	18.13	-13.7
20% Reduction in		
CAPEX	17.94	-14.6
OPEX	19.27	-8.2
IRR=7% with tax holiday	14.95	-28.8
Base Demand + CHP	**824 kton**	
	$/MMBtu	%
Base Scenario	7.46	
10 year tax holiday	6.50	-12.8
20% Reduction in		
CAPEX	6.40	-14.1
OPEX	6.82	-8.6
IRR=7% with tax holiday	5.44	-27.0
Base Demand + Zuzu	**1,801 kton**	
	$/MMBtu	%
Base Scenario	3.47	
10 year tax holiday	3.01	-13.1
20% Reduction in		
CAPEX	2.94	-15.1
OPEX	3.20	-7.8
IRR=7% with tax holiday	2.51	-27.6



Source: JICA Study Team

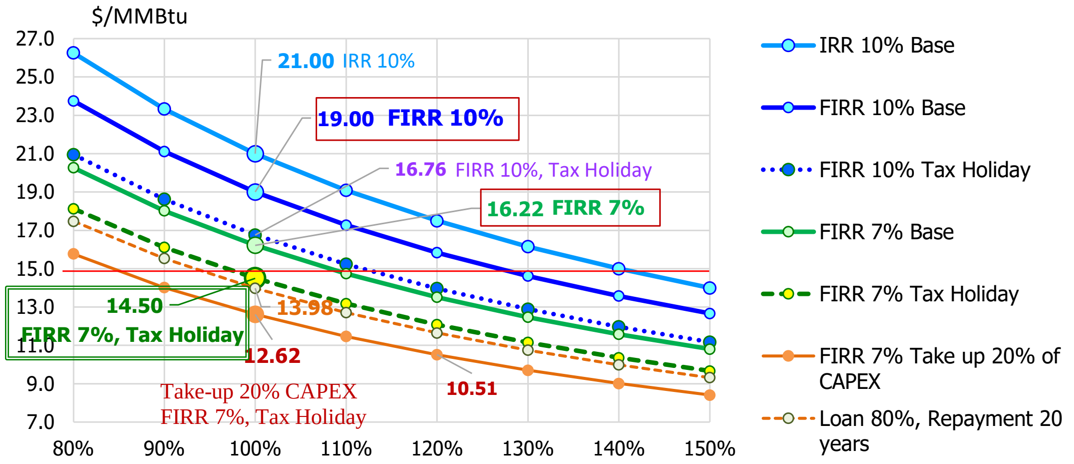
Figure 11.4-9 City Gas Company: Cost Composition and Sensitivity

Let us consider how policy options work on the Base Demand Case. As shown in Figure 11.4-10, switching the evaluation criteria from IRR to FIRR, the required toll goes down by $2/MMBtu from $21/MMBtu to $19/MMBtu. Then, the required toll will be reduced with 10 year tax holiday to $16.76/MMBtu. If the project criterion is lowered to FIRR=7%, it will be reduced further. Extending the loan repayment period from 10 years to 20 years, it goes down slightly. If 20% of CAPEX is taken up by subsidy, it goes down by $2/MMBtu. And generally speaking, when market is small, volume increase works extensively.

From these analyses, it is recommendable to adopt proactive policies as below:

a. Prepare good business circumstance and beneficial finance that would allow lower project threshold.
b. Provide tax holiday for the business build-up period, for example, 10 years.
c. Provide subsidy for investment if market is small.
d. Promote use of city gas at public facilities and schools to create base demand.

With proactive policy actions as above, we may be able to achieve a toll of $15/MMBtu.



Source: JICA Study Team

Figure 11.4-10 Policy Options on City Gas Development

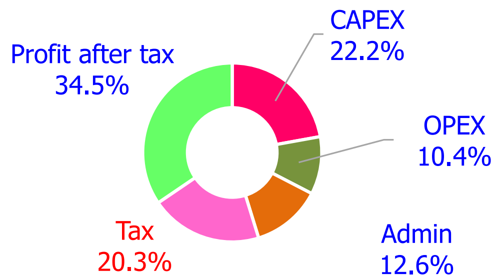
In its history, city gas system has been developed as a part of social infrastructure. City gas supply system for minor users only would be extremely expensive. Unless some large anchor demands to provide the business platform, city gas is not readily viable as commercial business. Similar situation is observed in Southeast Asian countries where LPG is penetrating fast instead of piped city gas network. However, once the upfront investment has been depreciated, daily cost will become relatively small compared with LPG that requires delivery of cylinders. From these observation, introduction of city gas system should be discussed from the overall view point with regard to socio-economic development of the country for better quality of life, urban development plan and preservation of environment.

11.4.4 Bulk Delivery Users

In Table 11.3-4 and Figure 11.4-11, cost of gas facilities at large users is assessed in the same manner as applied for other sectors as if it is a commercial business. However, it would not be appropriate to apply this method of approach as users would not count any commercial return as the cost. Rather, such cost may be assessed on instalments payback basis.

Sensitivity Analysis at IRR=10%

	Required Tariff	
	$/MMBtu	%
Base Scenario	6.03	
10 year tax holiday	5.15	-14.5
20% Reduction in		
CAPEX	4.82	-20.0
OPEX	5.86	-2.8
IRR=7% with Tax Holiday	4.16	-31.0



Source: JICA Study Team

Figure 11.4-11 Satellite Cost at Bulk Users: Cost Composition and Sensitivities

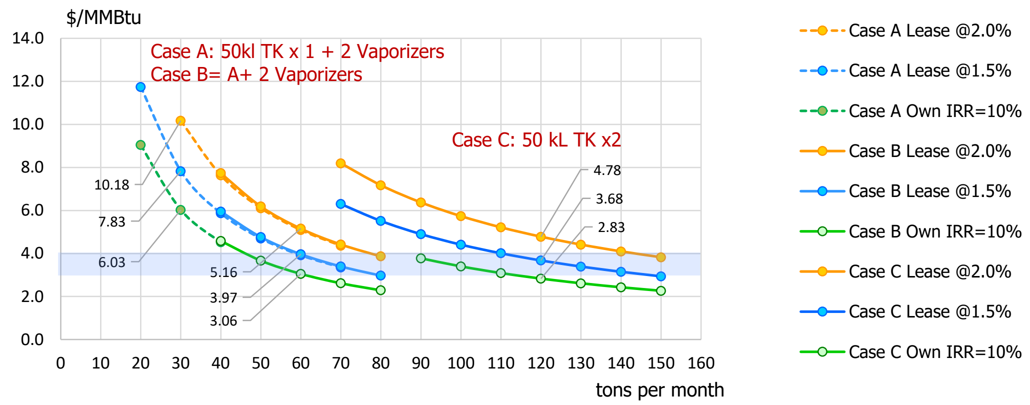
We estimate costs for gas handling facilities at large industrial users as shown in Table 11.4-2 below.

Table 11.4-2 Bulk Delivery Users

	Specification		Price	A. Storage 50kL 360 tons/year		B. Storage 50kL 720 tons/year		C. Stroage 100kL 1,800 tons/year		D. Stroage 300kL 3,600 tons/year	
			$k		$k		$k		$k		$k
LNG Storage Tank	50	kL	240	1	240	1	240	2	480		
	150	kL	430							2	860
Vaporiser	0.05	t/h	5	2	10	4	20				
	0.2	t/h	20					2	40		
	0.8	t/h	80							2	160
Other Equipment					120		120		130		160
Piping Installation					60		60		150		810
Electric Instruments					50		50		130		690
Civil and Office Building					50		50		150		630
Sub-total					530		540		1080		3310
Engineering & Comissioning				40%	210	39%	210	29%	310	9%	310
Total					740		750		1390		3620

Source: JICA Study Team

Figure 11.4-12 shows changes in satellite tariff at large users according to monthly demand size; this may also be applicable to consideration of small scale community gas grid. It shows the tariff using a lease system at monthly fee of 2% and 1.5% of the upfront CAPEX as well as the ordinary ownership approach. The assumed capacities are excessive for small energy users who take up less than 30 tons per month. Excluding users to use much smaller facilities, the gas handling facility cost is estimated to be in the range of $3.00-4.00/MMBtu.



Source: Study Team

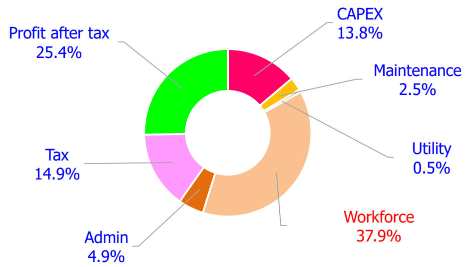
Figure 11.4-12 Satellite Tariff for Bulk Delivery Users

11.4.5 Natural Gas Service Station

Economics of a natural gas service station is calculated assuming a business development plan developed in section 7.4; namely, gas sale starts in 2025 at round 170 tons per month with 150 daily visitors, and reaches 500 tons with over 500 visitors around 2030 as the first target. Cost for operating a natural gas service station is estimated to be $2.97/MMBtu. This represents a standalone case including investment for LNG tanks. At a gas station attached to a satellite terminal, storage tanks may be shared reducing the investment amount by 10-30%.

Sensitivity Analysis at IRR=10%

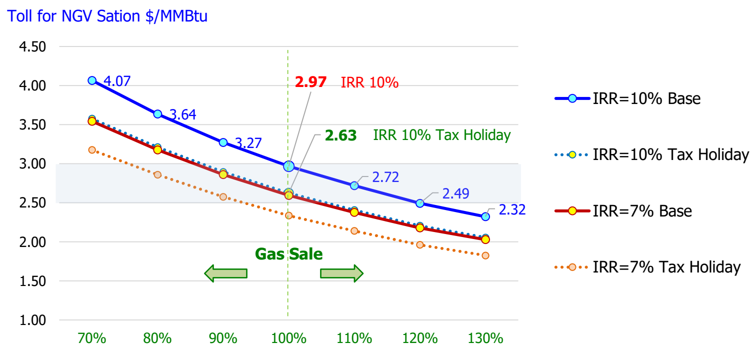
	Required Toll	
	$/MMBtu	%
Base Scenario	2.97	
10 year tax holiday	2.63	-11.5
20% Reduction in		
CAPEX	2.69	-9.3
OPEX	2.63	-11.5
IRR=7% with Tax Holiday	2.34	-21.3
Sales Volume		
120%	3.37	13.4
80%	5.05	70.2



Source: JICA Study Team

Figure 11.4-13 Natural Gas Service Station: Cost Composition and Sensitivity

At a natural gas service station, the wage for operators is the single largest cost item. As the sales amount is small, changes in preconditions for sales amount brings large impacts on the absolute value of the required toll. For example, 10 year tax holiday reduces the required toll by $0.34/MMBtu from $2.97/MMBtu to $2.63/MMBtu, or 11.5%. This is larger than the impact of a 20% reduction in CAPEX. On the other hand, 20% reduction in OPEX brings down the required toll to $2.63/MMBtu or a 11.5% reduction, though it is difficult to control this element.



Source: JICA Study Team

Figure 11.4-14 Natural Gas Service Station

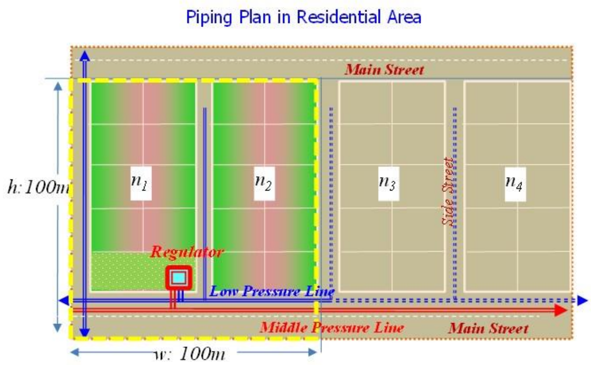
Cost of running a natural gas service station also changes according to sales amount. However, it may be in the range of $2.50-3.50/MMBtu as shown in Figure 11.4-14.

11.4.6 Community Gas Supply System

One of the benefits of the virtual pipeline system is that it is possible to deliver natural gas to relatively small communities not connected to any gas pipeline. Smaller communities away from gas pipeline will be able to develop community gas system. To examine its economics, we set out hypothetical profile of a community with dense population. Let us consider a block of one hectare (100m x 100m) facing one main street of 16m wide and having two side streets of 8m wide. Then road occupies 29.4% of the block. The remaining space may be allocated 20% for public use such as schools, government/community offices and facilities, parks, athletic fields, green reserves, etc, and another 20% for business and commercial activities such as for business offices, shops, restaurants, hotels, hospitals, etc, the remaining space for residence will be 42.3%. Factories may be separately put in an industrial estate and therefore not considered here. Assuming an average of 20 slots for the residential space, space for one slot is 212 m^2. If 20% of the residential land is not used, there will be 16 houses, and, with 5 persons for a family, the total population of the block is 80 persons; if 6 per family, 96 persons. This calculation may look very loose. But it compares to the population density of Yokohama city (86 persons per hectare), the second largest city in Japan with population of 3.7 million.

Table 11.4-3 Profile of Hypothetical Community for Piped Gas Supply System

Total Area	100 m	100 m	10,000 m^2
Road	Main Sreet	Side Street	
Width	16 m	8 m	
Number	1	2	
Total			2,944 m^2
Public Space	20%		1,411 m^2
BizCom Area	20%		1,411 m^2
Residential Area			4,234 m^2
Open Land	20%		847 m^2
Housing Land	80%		3,387 m^2
Houses per block	20 slots	Residing 16	houses
Land per house			212
Coverage	50%	Single Story	2 stries
House size		106 m^2	212 m^2
Family member	5	persons	
Population	80	persons	
Gas Consumption	100	kg/person/year	
Annual Demand	8	tons/yers	



Applying the above profile, features of smaller communities and community gas systems are summarized in Table 11.4-4. Gas demand at each community is estimated assuming that the residential gas consumption is 100 kg per year per person with 20% additional gas demand of business/commercial sector on top of it. As the sector is assumed to occupy 20% of the land, this means that fuel intensity of the sector is same with that of the residential sector. This may be a conservative assumption.

Then, the community gas is designed as follows:

<u>Satellite Terminal</u>

a. Satellite terminal will have one or more units of 50 kL LNG storage tank to keep at least one week storage plus ullage to receive an 18-ton container. Price is $240,000 per unit.
b. Vaporisers at the satellite terminal will be several units of 0.05 -0.2 ton per hour capacity. Price is $5,000 per unit for a 0.05 ton/hour vaporiser and $20,000 for a 0.2 ton/hour unit.
c. Cost for other equipment, construction and commissioning will be $480,000 – 580,000.

Community Gas System

d. Governor (regulator) will be set one for 1 km^2: $50,000.

e. Middle pressure pipeline will be built to link governors: (number of governors - 1) km: $550,000/km

f. Low pressure pipeline will be laid down along every side street plus the main street: $180,000/km

g. Connection cost will be $1,300 per house.

Table 11.4-4 Size of Community and Piped Gas Supply System

Case	Community			Residential Feature			Gas Demand		
	Width	Length	Area	Area	House	Population	Residentai l	Total	
	km	km	ha	ha			t/y	t/y	t/ha
A	0.1	0.5	5	2.1	80	400	40	50	10
B	0.2	0.5	10	4.2	160	800	80	100	10
C	0.5	0.5	25	10.6	400	2,000	200	240	10
D	0.5	1.0	50	21.2	800	4,000	400	480	10
E	1.0	1.0	100	42.3	1,600	8,000	800	960	10
F	1.0	1.5	150	63.5	2,400	12,000	1200	1440	10
G	1.0	2.0	200	84.7	3,200	16,000	1600	1920	10

Case	Area Size	Demand	Satellite		Gas Network			Total Cost	
			LNG Tank	Vaporiser	Governer	Medium Pressure	Low Pressure		
	ha	t/y				km	km	$k	$k/ha
A	5	50	1	2	1	0.0	0.7	1,080	216
B	10	100	1	2	1	0.0	1.4	1,340	134
C	25	240	1	2	1	0.0	3.4	2,200	88
D	50	480	1	3	1	0.0	6.8	3,425	69
E	100	960	2	2	1	0.0	13.6	6,330	63
F	150	1440	2	2	2	1.0	20.4	9,520	63
G	200	1920	3	3	2	1.0	27.2	12,320	62

As shown in the table, gas demand per hectare is kept at 10 tons per year for all cases, while the construction cost per hectare dramatically changes when the total demand is small. It stabilizes at the total gas demand of around 500 tons per year or a community of 800 houses.

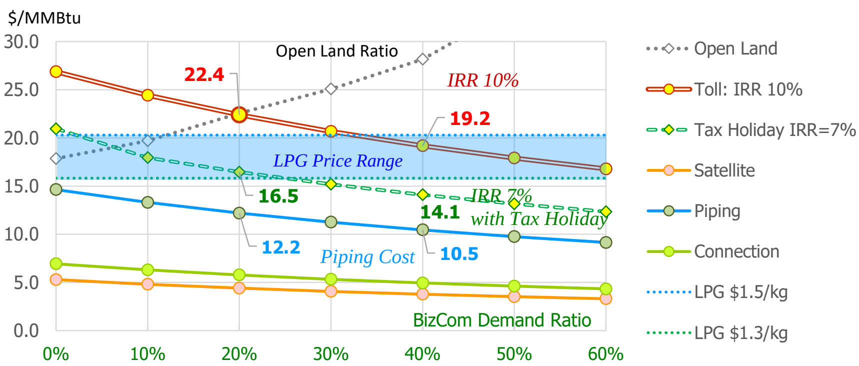
Table 11.4-5 Cost of Community Gas by Market Size

Case	House	City Gas Charge					City Gas Price		Tax Holiday IRR=7%	
		Satellite	Piping	Connection	Total	Tax Holiday IRR=7%	LNG delivered to Satellie at $13.06/MMBtu (See Table 12.6-2)			
		$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/kg	$/MMBtu	$/kg
A	80	57.9	13.0	5.2	76.1	56.4	89.2	4.00	69.5	3.28
B	160	30.2	12.9	5.5	48.6	36.6	61.8	2.77	49.7	2.35
C	400	13.1	12.4	5.6	31.2	23.2	44.3	1.99	36.3	1.72
D	800	7.1	11.8	5.8	24.7	18.1	37.9	1.70	31.3	1.48
E	1600	4.4	12.2	5.8	22.4	16.5	35.5	1.59	29.6	1.40
F	2400	2.9	13.4	5.8	22.2	16.3	35.3	1.58	29.4	1.39
G	3200	2.6	13.0	5.8	21.3	15.6	34.4	1.54	28.7	1.36

Costs of community gas system and delivered gas prices are calculated as shown in Table 11.4-5. Costs for piping and connection are mostly same and the total cost for smaller communities goes up due to inflexible satellite cost. It is apparent that construction of a standalone system for such smaller communities is difficult. However, as discussed in Section 11.4, if an L-CNG station is built at near location which sells 3,000 tons or more natural gas a year, such community can co-use the satellite at the station. Then the satellite cost will be dramatically reduced to $3.00/MMBtu or so.

The calculated gas prices equivalent to LPG are in the range of $1.60-2.00/kg for cases C-G. This looks expensive compared with the present LPG price in the market. However, with some counter measures such as tax holidays and lowered commercial criterion, it can also be lowered to some competitive level.

To consider a community gas system, the gas demand volume of the service area and its density are the most important factors. As demand volume increases, the competitive edge will improve considerably. In the above calculation, we assume that the energy intensity of the business/commercial sector is same with that of the residential sector. If it is double (the BizCom demand ratio in the Figure 11.4-5 goes up from 20% to 40%), the required tariff for Case-E goes down from $22.4/MMBtu to $19.2/MMBtu by 14%. In general, energy intensity is much higher in business, commercial and industrial sectors than households. If there are certain large energy users such as hotels, shopping malls, L-CNG stations and factories, community gas system will be viable even in a small town with co-use of the supply system. Without them, the community must be large enough to provide a threshold demand for the system.



Source: JICA Study Team

Figure 11.4-15 Sales Volume and Community Gas Tariff

In summary, standalone community gas system may be considered for a town of 1,000 houses *densely distributed* under the present preliminary cost assumptions. In addition, if there are any active energy users that would dilute the satellite cost, the threshold can be significantly lowered. In Table 11.4-5, for example, if the satellite cost is lowered to $3.0/MMBtu sharing the satellite at an L-CNG station, even Case-A community with 80 houses may be able to enjoy community gas system. In this case, however, gas use of the larger energy users must be confirmed at first. It is needless to say but specific conditions of a community must be examined one by one to consider a real project.

11.5 Summary of Economic Analysis

11.5.1 Cost Composition

In summary of the foregoing analysis, the total cost excluding the feedgas cost incurred during the entire project period of 25 years is compiled by sector in Table 11.5-1. Although the upfront investment amount is important to decide the project feasibility, other cost items are also important when the cost composition for the entire project period is considered.

Table 11.5-1 Cost by Sector and Cost Element

	Plant	Transport	Satellite	City Gas	Connection	NGV 5 SS	Total	
Amount for 25 years	$ million	$ million	$ million	$ million	$ million	$ million	$ million	
CAPEX	148.8	32.4	37.0	52.1	10.6	18.3	299.2	16.2%
Operation & Maintenance	154.8	10.1	9.3	13.0	2.7	3.4	193.2	10.5%
Fuel	56.2	70.9	4.6	6.5	1.3	0.7	140.3	7.6%
Operator/Driver	40.3	19.9	28.1	22.5	0.0	50.3	160.9	8.7%
Admin & Marketing	40.6	16.8	7.5	55.3	0.0	6.5	126.7	6.9%
Sub- Total	440.7	150.1	86.4	149.4	14.6	79.1	920.4	49.8%
Tax	220.7	7.8	86.4	52.0	8.0	19.7	394.7	21.4%
Profit after tax	375.8	13.3	35.1	88.5	13.6	33.6	560.0	30.3%
Total	1,037.3	171.1	181.3	289.9	36.3	132.4	1,848.4	100.0%
	56.1%	9.3%	9.8%	15.7%	2.0%	7.2%	100.0%	
Composition	%	%	%	%	%	%	%	
CAPEX	33.8	21.6	42.8	34.9	72.7	23.1	32.5	
Operation & Maintenance	35.1	6.7	10.7	8.7	18.2	4.2	21.0	
Fuel	12.8	47.2	5.4	4.4	9.1	0.9	15.2	
Operator/Driver	9.1	13.2	32.5	15.1	0.0	63.5	17.5	
Admin & Marketing	9.2	11.2	8.7	37.0	0.0	8.2	13.8	
Sub-Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
Tax	50.1	5.2	100.0	34.8	54.8	24.9	42.9	
Profit after tax	85.3	8.9	40.6	59.2	93.3	42.5	60.8	
Profit +tax	135.4	14.1	140.6	94.0	148.1	67.4	103.7	

Source: JICA Study Team

Among sectors, investment amount is largest in the LNG plant sector. Therefore, it is foremost important to make this sector viable. As discussed in Section 11.4.1, plant size is the most important factor to decide economics. To define the plant size, it is at first necessary to establish the prospective demand size and its development profile.

Second largest sector is the city gas sector. However, it is difficult to justify construction of a gas distribution system for minor users by way of ordinary economic approach. Unit connection cost for such users like households, small shops and restaurants will be extremely expensive. It needs to be treated differently with a view to implement gasification as a whole society to improve quality of life and environment. If the business platform is firmly established by other commercial demand with some economic rent or surplus profit and thus upfront financing is assured, investment in the city gas sector to serve minor users can be absorbed as a whole project. On the other hand, unit cost for gas distribution is relatively small for large users and the applicable toll may be decided as commercial transaction.

As a result that criteria for commercial business are applied in the above analysis, financial cost represented by the fair profit and tax is high. However, costs for inlet pipe connection and users' facilities should be assessed by the actual expenditure only. Commercial return on such investment would not be necessary when they are compared with other fuels.

Fuel cost dominates in the transport sector while administration and personnel cost dominate in the city gas sector and at gas service stations. Switching truck fuel to gas, transportation cost will be lowered as analysed in the next section. Administration cost which is mostly personnel cost will be diluted as the business expands. In this regard, personnel support in the early stage of gasification will substantially contribute to make the project viable.

11.5.2 Sensitivity Analysis

Sensitivity analysis by sector is compiled in Table 11.5-2 for the Base Demand scenario and the "plus Zuzu" High Demand scenario. Impacts of introducing a ten (10) year tax-holiday, 20% reduction in CAPEX and OPEX, and reduced target of project economics to IRR=7% with a ten year tax-holiday are examined. Impacts of these events are different among sectors.

Table 11.5-2 Summary of Sensitivity Analysis by Sector

	LNG Plant		Transport		Satellite		City Gas		Total (City Gas)		NGV SS	
Feedgas price @ $5.36 (14.8%)	$/MMBtu	%	$/MMBtu	%	$/MMBtu	%	$/MMBtu	%	$/MMBtu	%	$/MMBtu	%
Base Demand Scenario	9.89	24.1	1.59	3.9	3.15	7.7	21.00	51.2	40.98	100.0	2.97	15.0
Sensitivity		%										
10 year Tax Holiday	8.46	-14.5	1.56	-1.7	2.74	-13.0	18.13	-13.7	36.24	-11.6	2.63	-11.5
20% Reduction: CAPEX	8.28	-16.2	1.50	-5.8	2.80	-11.3	17.94	-14.6	35.87	-12.5	2.69	-9.3
OPEX	9.29	-6.0	1.36	-14.2	2.87	-8.7	19.27	-8.2	38.16	-6.9	2.63	-11.5
Fuel	9.78	-1.1	1.46	-7.9	na		na				na	
IRR=7% with tax holiday	6.82	-31.0	1.52	-4.5	2.25	-28.5	14.95	-28.8	30.90	-24.6	2.34	-21.3
Feedgas price @ $5.36 (31.4%)		%		%		%		%		%		
High Demand With Zuzu PS	5.89	33.2	1.49	8.4	1.54	8.7	3.47	19.5	17.74	100.0		
Sensitivity												
10 year Tax Holiday	5.11	-13.2	1.46	-2.0	1.33	-13.5	3.01	-13.1	16.27	-8.3		
20% Reduction: CAPEX	4.97	-15.6	1.40	-6.0	1.33	-13.6	2.94	-15.1	16.00	-9.8		
OPEX	5.55	-5.7	1.28	-14.1	1.44	-6.4	3.20	-7.8	16.82	-5.2		
Fuel	5.78	-1.8	1.37	-8.1	na		na					
IRR=7% with tax holiday	4.28	-27.2	1.42	-4.4	1.10	-28.4	2.51	-27.6	14.68	-17.3		

Source: JICA Study Team

Among others, changes in the demand size between two cases brings a big difference in the LNG plant sector and the city gas sector. This is because the plant utilisation rate is improved significantly on one hand, and the city gas sector overhead is diluted with the big amount of gas supply for the power station. On the other hand, tolls required for the transport sector and the satellite terminals are relatively stable. This is because capital expenditure in these sectors changes flexibly according to business size.

At the same time, the absolute values of these impacts are different among sectors and this is an important point to consider policy actions. For example, in the city gas project, a ten year tax holiday brings about cost reduction of $1.43/MMBtu in the LNG plant sector, $0.03/MMBtu in the transport sector, $0.41/MMBtu in the satellite sector and $2.87/MMBtu in the city gas distribution sector, respectively; in total $1.87/MMBtu for the ex-satellite gas price and

$4.74/MMBtu for the city gas delivered price. In the natural gas service station project, it brings about cost reduction of $1.43/MMBtu in the LNG plant sector and $0.03/MMBtu in the transport sector, while $0.34/MMBtu in the gas service station sector, respectively, and total $1.80/MMBtu.

From this observation, the transport and satellite sectors have relatively small impacts on the project. On the other hand, in-depth study is necessary on the plant sector, city gas sector and the gas service station sector.

It is also observed that, lowering the profitability target, the required toll will be significantly reduced. However, to make the project "bankable," a healthy financial structure must be secured. This issue should be examined carefully to bring a prudent balance of the public interest and healthy project structure.

11.6 Standard Model and Economics of Virtual Pipeline

11.6.1 Prices of Petroleum Products

Traditional biomass such as firewood and charcoal dominates in the energy market of Tanzania. As discussed in Part-1, firewood is being rapidly replaced with charcoal in urban areas. Economic growth will further enhance switching of these fuels to modern fuels. In this process, directly competitive energy sources for natural gas are petroleum products and, to some extent, electricity. They are;

a. Industrial sector: LPG, diesel gas oil, fuel oil and electricity
b. Business/commercial sector: LPG, diesel and electricity
c. Transport sector: petrol and diesel
d. Household sector: LPG, kerosene and electricity

Among them, LPG is penetrating rapidly, while natural gas is presently available only in Dar es Salaam. In Tanzania, prices of petrol, diesel and kerosene are regulated by EWURA, and the latest applicable cap prices are as shown in Table 11.6-1. Electricity toll is also regulated by category of users. On the other hand, prices of heavy fuel oil and LPG are not regulated at present. Heavy fuel oil price ex-depot was TzS1,526/litre or US$0.66/litre in September 2021. Adding up TzS188, retail price in Dodoma will be TzS1,714/litre or $0.74/litre.

Table 11.6-1 Cap Prices of Petroleum Products: September 2021

at 2,311 Tzs/USD

		Petrol	Diesel	Kerosene	Petrol	Diesel	Kerosene
		Tzs/ltr	Tzs/ltr	Tzs/ltr	US$/ltr	US$/ltr	US$/ltr
Retail Price	Dar es Salaam	2,427	2,251	2,176	1.05	0.98	0.94
	Dodoma	2,486	2,310	2,234	**1.08**	**1.00**	**0.97**
	Tanga	2,486	2,324	2,222	1.08	1.01	0.96
Wholesale Price	Dar es Salaam Port	2,297	2,122	2,047	1.00	0.92	0.89
	Tanga Port	2,356	2,194	-	1.02	0.95	-
Balance	DSM -->Dodoma	189	188	187	0.08	0.08	0.08

Source: EWURA

LPG prices observed in Dodoma in November 2018 and September 2021 were as shown in Table 11.6-1. These are the prices sold at service stations and gas shops. LPG cylinders may need to be delivered to or carried home. According to the Regional Energy Demand Survey conducted by the Study team, a standard household of 4-6 family members consumes one or two 15kg cylinders a month while charcoal may also be consumed to make meals.

November 2018(Dodoma)

2305 TzS/USD

Cylinder Size	LPG	plus Cylinder	Cylinder Price
	Tzs	Tzs	Tzs
6 kg	22,000	45,000	23,000
15 kg	53,000	94,000	41,000
38 kg	118,000	218,000	100,000
	$/kg LPG		$
6 kg	1.59		10.0
15 kg	1.53		17.8
38 kg	1.35		43.4

October 2021(Dodoma)

2311 TzS/USD

Cylinder Size	LPG	plus Cylinder	Cylinder Price
	Tzs	Tzs	Tzs
3 kg	9,000	33,000	24,000
6 kg	17,500	37,000	19,500
15 kg	45,000	87,000	42,000
38 kg	85,000	185,000	100,000
	$/kg LPG	Change	$
3 kg	1.30		10.4
6 kg	1.26	-20.7%	8.4
15 kg	1.30	-15.3%	18.2
38 kg	0.97	-28.2%	43.3

Source: JICA Study Team

Figure 11.6-1 LPG Price in Dodoma (November 2019)

As shown in Figure 11.6-1, retail LPG price dropped 15%-20% since 2018. This may be reflecting the global oil and gas price collapse occurred in 2020 caused by COVID-19 pandemic that paralyzed world economy in addition to over production of shale oil in the United States. However, world energy prices rebounded in early 2021 and, particularly, gas price is going up rapidly as discussed in Chapter 2. As price variance by cylinder size is irregular in 2021 prices, we consider the reference price of LPG at $1.30/kg in this report.

11.6.2 Model Virtual Pipeline

In summary of the analysis in Section 11.4, we estimate the toll for the model virtual pipeline to transport natural gas to Dodoma as shown in Table 11.6-2. Gas prices are converted into equivalent prices of petrol, kerosene, diesel and LPG applying the net calorific values as shown in the table. The model is projected as below.

A mini-LNG plant with a capacity of 200 tons/day x 2 trains will be operated at 80-90% load. Though this assumes a higher demand than the Base Demand scenario developed in Section 11.1 (plant utilisation at 60.5%), it may be achievable with marketing efforts to find more industrial customers and accelerated development of NGV service station network.

With exemption of import duty on containers and vehicles, the transportation cost for Dodoma may be lowered from $1.85/MMBtu to $1.67/MMBtu as shown in Figure 11.4-4. Switching truck fuel to natural gas will also contribute to lower the toll. We adopt $1.70/MMBtu for the model case.

The satellite terminal cost is assumed at $3.00/MMBtu as calculated for the Base Demand case in Figure 11.4-6. If demand is increased with accelerated gasification, it will be lowered.

Table 11.6-2 Toll for Virtual Pipeline for Dodoma

				Base Demand		Base Demand +CHP	
				$/MMBtu	$/ton LNG	$/MMBtu	$/ton LNG
Feedgas Price				5.36	281	5.36	281
LNG Plant				6.00	315	6.00	315
Transport for Dodoma by container				1.70	89	1.70	89
LNG Delivered to Dodoma				13.06	686	13.06	686
Satellite Terminal				3.00	158	1.80	95
Virtual Pipeline				10.70	562	9.50	499
Natural Gas Ex-Satellite in Dodoma				16.06	843	14.86	780
Equivalent to			Current Price				
Oil	10,000	kcal/kg		0.64	$/kg	0.59	$/kg
Petrol	7,900	kcal/ktr	1.08	0.50	$/ltr	0.47	$/ltr
Diesel	8,600	kcal/ktr	1.00	0.55	$/ltr	0.51	$/ltr
LPG	11,300	kcal/kg	1.30	0.72	$/kg	0.67	$/kg

Source: JICA Study Team

As a result, the total toll for the virtual pipeline to transport natural gas to Dodoma by way of LNG is estimated at $10.8/MMBtu or $567/ton of LNG. This toll can be reduced with enhanced efforts to accelerate gasification. However, if the demand build-up is slower, it will push up the unit cost in particular in the LNG plant sector.

11.6.3 Natural Gas Prices for Bulk Users and NGVs

At bulk users, gas receiving and vaporisation cost will be in the range of $3.00-4.00/MMBtu subject to the handling volume. The gas price at burner tip will be about $17/MMBtu or $660/toe which will be competitive with imported petroleum products with a significant margin.

At Gas service stations, the pump price will be less than $18/MMBtu or $1,000/toe. Compared with the September 2021 cap prices announced by EWURA, natural gas price is 54% lower than that of petrol and 45% lower than diesel. Although upfront preparation requires hard work to introduce NGVs into Tanzania, it will bring substantial benefit in terms of economics as well as environment.

Table 11.6-3 Toll for Bulk Users and Gas service stations

				Bulk Users		NGV Stations	
				$/MMBtu	$/ton LNG	$/MMBtu	$/ton LNG
Feedgas Price				5.36	281	5.36	281
LNG Plant				6.00	315	6.00	315
Transport for Dodoma by container				1.70	89	1.70	89
Satellite (receiving and vaporisation)				**4.00**	210		
NGV Station						**3.00**	158
Virtual Pipeline				11.70	614	10.70	562
At Burner Tip or Pump				**17.06**	896	**16.06**	843
			Current Price				
Oil	10,000	kcal/kg		**0.68**	$/kg	0.64	$/kg
Petrol	7,900	kcal/ltr	1.08	0.53	$/ltr	**0.50**	$/ltr
Diesel	8,600	kcal/ltr	1.00	0.58	$/ltr	**0.55**	$/ltr
Fuel Oil	9,700	kcal/ltr	0.74	0.66	$/ltr	0.62	$/ltr
LPG	11,300	kcal/kg	1.30	0.77	$/kg	0.72	$/kg

Source: JICA Study Team

11.6.4 City Gas

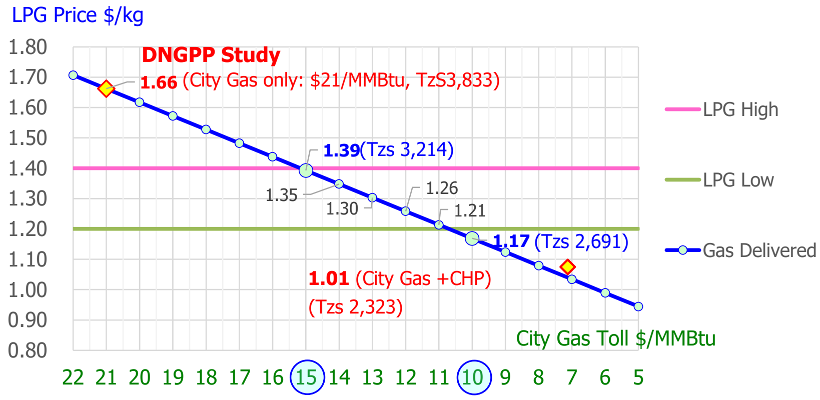
As discussed in Section 11.4.3, the city gas sector is not readily viable when targeting the minor consumers only. As summarised in Table 11.6-4, the required toll at the city gas sector for the Base Demand case is high due to small sales amount. As a result, the delivered gas price will be $1.66 per kg in LPG equivalent, which is slightly higher than the LPG prices prevailing in the market. However, the toll dramatically reduces if some anchor demand is prepared such as CHPs.

Table 11.6-4 Natural Gas Prices for City Gas in Dodoma

Case				Base Demand		Base Demand +CHP	
LNG Sale for 25 years				316	kt	824	kt
				$/MMBtu	$/ton LNG	$/MMBtu	$/ton LNG
Ex-Satellite				16.06	843	14.86	780
City Gas Network				18.47	970	6.63	348
Connection				2.53	133	0.83	43
City Gas Charge				**21.00**	1,103	**7.46**	392
City Gas Delivered				37.06	1,946	22.32	1,172
Equivalent to			Current Price				
Oil	10,000	kcal/kg		1.47	$/kg	0.89	$/kg
Petrol	7,900	kcal/ltr	1.08	1.16	$/ltr	0.70	$/ltr
Diesel	8,600	kcal/ltr	1.00	1.26	$/ltr	0.76	$/ltr
Fuel Oil	9,700	kcal/kg	0.74	1.43	$/kg	0.86	$/kg
LPG	11,300	kcal/kg	1.30	**1.66**	$/kg	**1.00**	$/kg

Source: JICA Study Team

Given the ex-satellite gas price of $16.06/MMBtu, how much can be the city gas toll to be competitive with LPG? LPG price prevailing in Dodoma is around $1.30 per kg of LPG (not including the cost for LPG cylinder and delivery). Then, as shown in Figure 11.6-2, the city gas toll must be lower than $15/MMBtu; it is desirable if the toll can go down below $12/MMBtu. In addition, as the case for adoption of CHP which would create additional demand of 30,000 tons per year on top of 12,500 tons for city gas, the city gas tariff will be surprisingly diluted to $7.46/MMBtu or $1.00/kg LPG equivalent. Demand volume is crucial to justify city gas system.



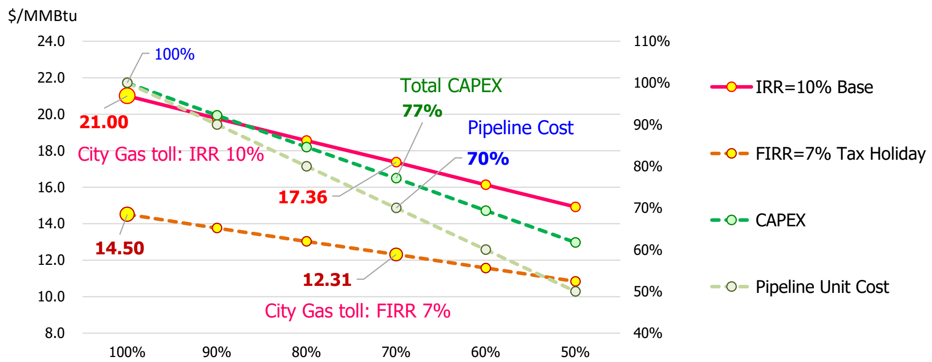
Source: JICA Study Team

Figure 11.6-2 City Gas Toll to compete with LPG

The above calculation is made applying the unit costs of city gas construction observed in Japan. However, the civil work portion of pipe laydown may be cheaper in Tanzania. If they are cheaper by 30%, the total upfront capital expenditure will be reduced by 23%, and the required city gas toll will decrease from $21.00/MMBtu to $17.36/MMBtu. It will be further improved if 10 year tax holiday is applied and the project threshold is lowered to FIRR=7%. The city gas price equivalent to one kg of LPG goes down from $1.67 to $1.50 for the Base Case and from $1.37 to $1.28 for the tax holiday case.

Table 11.6-5 Pipeline Construction Cost and Change in Toll

Pipeline Unit Cost			CAPEX	IRR=10%	FIRR=7%	LPG Price Equivalent	
	Medium	Low		Base	Tax Holiday	Base	Tax Holiday
	$/m	$/m		$/MMBtu	$/MMBtu	$/kg	$/kg
100%	550	180	100%	21.00	14.50	1.67	1.37
90%	495	162	92%	19.76	13.76	1.61	1.34
80%	440	144	85%	18.55	13.03	1.56	1.31
70%	385	126	77%	17.36	12.31	1.50	1.28
60%	330	108	69%	16.13	11.56	1.45	1.24
50%	275	90	62%	14.92	10.83	1.39	1.21

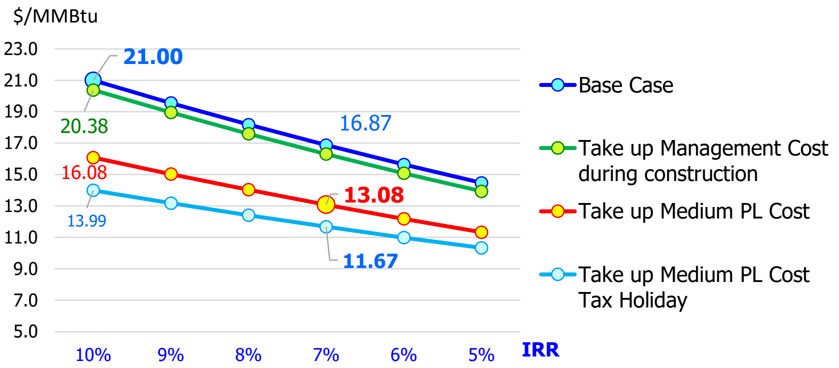


Source: JICA Study Team

Figure 11.6-3 Change in Capex and Required Toll for City Gas

In addition to this, there are several measures to be considered to reduce the city gas toll such as to;

a. Develop gas demand as much as possible.
   a) Consider co-use of the satellite and the city gas network with industrial users
   b) Take-up electricity demand of large users by way of CHP
b. Accelerate gasification to secure higher demand in the early stage.
   To this end, early formulation of technical teams for pipe connection and technical service teams to support users is very important.
c. Take up personnel cost of high officials during the early stage of the project, which may reduce the administration cost during construction by 30%.
d. Take up the investment cost for the medium pressure pipeline as the skeleton of the gas network.



Source: JICA Study Team

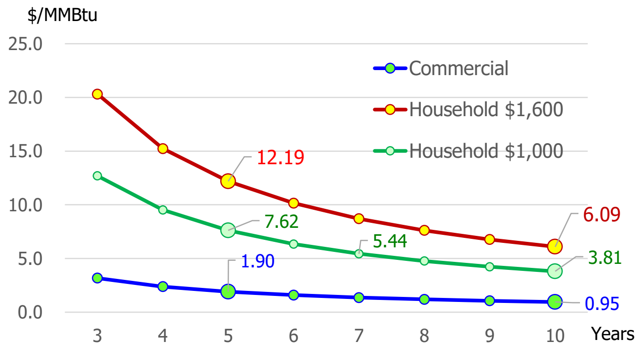
Figure 11.6-4 Lowering City Gas Toll

As another measure for reduction of the toll, a small scale power supply system may be introduced as a security measure for the core government offices, for example installing 5,000kW gas engine power generator. It may consume 300 tons of LNG per month and push up the demand level by 20%.

Autonomous power supply system

a. Generator: 2,500 kW x2
b. Utilisation at 50%, with efficiency of 40%
c. Annual fuel consumption: 4,700ktoe or 3,600 tons of LNG

The above calculation includes the inlet-pipe connection cost in order to examine competitiveness against other fuels. The connection fees shown in Table 11.6-4, $0.8-2.8/MMBtu, are the average cost calculated as the balance of the connection case and the non-connection case. However, the upfront connection cost is a big burden for small clients such as household, while it is a least problem for large users.



Source: JICA Study Team

Figure 11.6-5 City Gas Connection Cost Paid in Instalment

As discussed in Section 11.5.4, the upfront connection cost divided by the annual consumption is calculated to be $7.0/MMBtu for the commercial sector and, for the household sector, $60.9/MMBtu when the connection cost is $1,600 and $38.0/MMBtu when connection cost is $1,000. Figure 11.6-5 illustrates changes in annual payment if such cost is paid in instalment without interest.

For the medium-large users of gas, the connection cost would not be a problem. However, for the household sector, it is significantly high unless well designed. The connection cost of $1,600 per household is cited from Japanese examples. If it is cheaper in Tanzania, the problem may be alleviated significantly but would not disappear. It is necessary to further mitigate customers' hesitation toward introduction of city gas. To this end, some mechanism needs to be prepared to take up the upfront connection cost for minor users.

Table 11.6-6 City Gas Promotion Levy and NGV Fund

	Bulk Users	NGV Stations	City Gas	City Gas + CHP	Target
	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu
Feedgas Price	5.36	5.36	5.36	5.36	5.36
LNG Plant	6.00	6.00	6.00	6.00	6.00
Transport for Dodoma by container	1.70	1.70	1.70	1.70	1.70
SatelliteTerminal			3.00	1.81	1.80
Satellite (receiving and vaporisation)	4.00				
NGV Station		3.00			
Virtual Pipeline	11.70	10.70	10.70	9.51	9.50
Sub-Total	**17.06**	**16.06**	16.06	14.87	14.86
City Gas System			**18.47**	6.63	**8.00**
Connection			**2.53**	0.83	**2.00**
Total City Gas			**21.00**	**7.46**	**10.00**
City Gas Promotion Levy	**5.00**				
NGV Fund	0.20 $/kg	**5.00**			
Delivered Gas Price	**22.06**	**21.26**	**37.06**	**22.33**	**24.86**
Fuel Price Equivalent					
Oil 10,000 kcal/kg	0.88 $/kg	0.84 $/kg	1.47 $/kg	0.89 $/kg	0.99 $/kg
Petrol 7,900 kcal/ltr	0.69 $/ltr	**0.67** $/ltr	1.16 $/ltr	0.70 $/ltr	0.78 $/ltr
Diesel 8,600 kcal/ltr	0.75 $/ltr	**0.73** $/ltr	1.26 $/ltr	0.76 $/ltr	0.85 $/ltr
Fuel Oil 9,700 kcal/ltr No Levy	0.68 $/ltr	$/ltr	1.43 $/ltr	0.86 $/ltr	0.96 $/ltr
LPG 11,300 kcal/kg	**0.99** $/kg	0.95 $/kg	**1.66** $/kg	1.00 $/kg	**1.11** $/kg
Present Price in Dodoma	**Comparison**				
Petrol **1.08** $/ltr	64%	62%	108%	65%	72%
Diesel **1.00** $/ltr	75%	73%	126%	76%	85%
Fuel Oil **0.74** $/ltr	91%		193%	116%	129%
LPG **1.30** $kg	76%	73%	**128%**	77%	**86%**

Source: JICA Study Team

For example, we may aim at setting the city gas price at 85% of that of LPG with City Gas Promotion Fee to support minor users such as households and small/medium businesses. It may be sought from the economic rent expected from gas sale for other profitable sectors. NGV fund may also be considered. If they are assumed at \$5.00/MMBtu, the resultant gas price at bulk users and NGV drivers may be calculated as shown in Table 11.6-6. After such fund collection, gas prices are still sufficiently competitive with other fuels.

The total amount of the fund collected as above by 2030 will be \$23 million for the City Gas Fund and \$28 million for the NGV Fund. These will sufficiently cover the investment reduction in the city gas system and Gas service stations. However, some financial mechanism is necessary to prepare the fund for upfront investment before such fund is collected as time passes. Once operation has started, the upfront investment will be repaid and additional investment may be financed by such funds.

11.6.5 Summary

Findings of the above economic analyses are summarized as follows;

a. The natural gas supply by way of mini-LNG based *virtual pipeline system is viable* in comparison with other competitive fuels *once certain demand is confirmed.* In particular, the LNG plant sector is subject to economies of scale while having the largest cost composition. It is necessary to explore for several large users to provide anchor demand to expand the scale of the project.

b. For large users to receive LNG by bulk transport and NGV service stations, domestic natural gas is significantly cheaper compared with imported LPG and diesel gas oil. However, competition with cheap heavy fuel oil needs to be examined carefully taking account of its bulky volume effect.

c. On the other hand, city gas supply for minor users such as small shops, restaurants and households would not readily be viable as a commercially independent business. To develop this sector, it is necessary to prepare some mechanism to support upfront expenditure.

d. In view of the large profit margin in gas sale for other sectors, sufficient fund may be collected to construct the city gas system as well as introduction of natural gas vehicles. However, some amount should be prepared at the beginning to finance the upfront investment before the fund collection system yields fund. Such fund may also be allocated for other social development such as rural electrification.

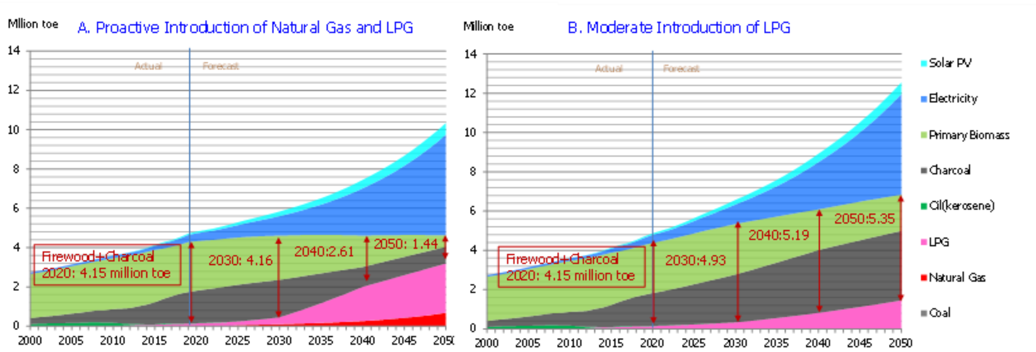
With above conclusion, it is foremost important to establish a credible gas sale plan to define the fundamental structure of the project. Gas demands are not readily available but need to be created in Tanzania. To this end, it is necessary to establish a comprehensive policy and prepare supporting institutions and programs to materialise them.

Chapter 12 Environmental and Social Considerations

12.1 Scenarios considered for environmental and social considerations on the domestic natural gas supply system

12.1.1 Implication of Natural Gas Introduction for environmental and social considerations

In Tanzania, traditional fuels such as firewood and charcoal are used widely as illustrated in Table 5.2-9; in particular, they comprise major part of the residential energy consumption (86.7% in 2020). As a result, people are facing with serious problems such as household air pollution during cooking, deforestation, work for firewood collection, etc. such as reported by the World Bank[72]. Introduction of natural gas and LPG is expected to improve the present conditions significantly.



Source: JICA Study Team

Figure 12.1-1 Consumption of Biofuel, Natural Gas and LPG: Residential Sector

In this study, we assume that, as shown on the left graph (A) of Figure12.1-1, natural gas and LPG will be introduced proactively increasing to 80% in 2050 of the residential fuel consumption (on fuel efficiency equivalent[73]). Then, consumption of firewood and charcoal combined will decrease to 1/3. As highly efficient gas stove is introduced, the total residential fuel consumption remains almost at the present level.

Compared with this projection, on the right graph (B), city gas is not introduced while LPG will penetrate mainly in urban areas but moderately from present 5% to 30% in 2050. Biofuel consumption will increase from the present 4.15million toe (including charcoal 1.67million toe) to 5.35 million toe in 2050 (including charcoal 3.45 million toe). Without remarkable improvement in energy efficiency, the total fuel consumption will also increase.

As explained later, degradation of forest resources is progressing rapidly in Tanzania; it is an urgent serious issue how to stop it. It would also be impossible to double the delivery of charcoal

72 World Bank, "Tanzania 2019 Country Environmental Analysis"
73 Fuel efficiency is assumed at 25% for firewood, 35% for charcoal and 50% for natural gas and LPG.

to urban areas. In order to alleviate forest degradation and achieve economic development simultaneously, it is essential to introduce modern energies. Then, natural gas is preferable compared with coal and oil because of its lower CO_2 emissions[74]. Switching motor fuel such as gasoline and diesel to natural gas, we can also reduce CO_2 emissions by 1/4 and also control foreign currency outflow for their import. As such the benefit of introducing natural gas will overwhelmingly exceed the anticipated demerits, this Study aims at proactive introduction of natural gas and mainly examines how and by what method we should materialise it.

12.1.2 Scenarios considered for environmental and social considerations

In this study, the following three scenarios are considered and compared at the higher level, Strategic Environmental Assessment (SEA) level, for domestic supply of natural gas in Tanzania. Please refer to other chapters for details of the proposed plan for each scenario.

For utilisation of modern energies which are indispensable for economic growth, indigenous natural gas is apparently beneficial in terms of GHG emissions as well as foreign currency outflow compared with coal and petroleum products. This study aims to contribute to development of economy and industry of Tanzania by way of introducing natural gas. Since this is achievable while the option not to implement said project as usually applied for environmental impact assessment is not conceivable, we do not conduct detail comparison by zero-option approach in this study.

Table 12.1-1 Scenarios considered for the Environmental and Social studies on the domestic natural gas supply system

Scenarios	Means of transport	Outline
Scenario 1	Gas Pipeline	Natural gas is transported by the 12-inch gas pipeline from the gas terminal in Kinyerezi area to Dodoma.
Scenario 2	Virtual pipeline (CNG)	Natural gas is compressed at the CNG plant in Kinyerezi area and transported by trucks and rail containers to the CNG satellites in Dodoma.
Scenario 3	Virtual pipeline (LNG)	Natural gas is liquefied at the mini-LNG plant in the Kinyerezi area and transported by trucks and rail containers to the LNG satellites in Dodoma.

Source: JICA study team

12.2 Policies and legal framework related to Environmental and Social considerations

The Ministry of Energy has developed "National Energy Policy 2015" and it includes policy statements on the environment, health, and safety. In order to promote environmental protection, health, and safety management in the energy sector, the following three statements are described

[74] CO_2 coefficient（Gg-CO_2/10^{10}kcal）… Coal:3.72, Gasoline:2.87, Diesel:2.88, HFO: 3.10, LNG:2.13 (Source: IEEJ “Handbook of Energy and Economic Statistics”)

in the policy.

The Government shall:

- Ensure that health, safety, environmental and biodiversity issues are mainstreamed into all operations of the energy industry;
- Ensure compliance to health, safety and environmental protection in the energy industry;
- Promote disaster prevention and response plans in the energy sector.

The "National Natural Gas Policy 2013" also includes matters related to environmental and social considerations as below.

- Promotion of CSR (Corporate Social Responsibility): To substantially improve Corporate Social Responsibility in communities neighbouring natural gas facilities and operations, the following two statements are described in the policy.

  The Government shall:

  - Ensure there is a contractual obligation to all investors and contractors in the natural gas activities to undertake locally prioritized community development programmes; and
  - Ensure companies in the natural gas industry submit credible Corporate Social Responsibility action plans to the appropriate authority.

- Management of the Environment, Health and Safety (EHS): To ensure compliance with Health, Safety and Environment standards in the natural gas value chain, following three statements are described in the policy.

  - Ensure that health, safety, environmental and biodiversity issues are mainstreamed into all operations of the natural gas value chain;
  - Ensure compliance to health, safety and environmental protection and best practice in the industry; and
  - Ensure disaster management systems to prevent and mitigate adverse impact in the natural gas operations are in place.

In this way, the Ministry of Energy is promoting i) EHS management in natural gas-related facilities, ii) disaster prevention measures, and iii) the promotion of CSR in the area where the facilities are located.

12.2.1 Legal framework on Environmental and Social Considerations in Tanzania

1) Legal framework for environmental management

The Environmental Management Act 2004 (EMA 2004) is a framework environmental law which provides for legal and institutional framework for sustainable management of the environmental and natural resources in the country. It includes provisions for institutional roles and responsibilities with regard to environmental management; Environmental Impact

Assessments; Strategic Environmental Assessments; pollution prevention and control; waste management; environmental standards; implementation of international environmental frameworks; implementation of national environmental policies, etc. Various regulations on environmental management have been developed in connection with the law (Table 12.2-1).

Table 12.2-1 List of Environmental Management Regulation in Tanzania

Category	Name of laws and regulations related to environmental management
Environmental management framework	· Environmental Impact Assessment and Audit Regulations (2005) · Strategic Environmental Assessment Regulations (2009) · Environmental Inspectors Regulations (2011) · Registration of Environmental Experts Regulations (2005)
Air quality, Noise and Vibrations	· Air Quality Standards Regulations (2007) · Noise and Vibrations Standards Regulations (2009)
Water quality	· Water Quality Standards Regulations (2007)
Soil quality	· The Soil Quality Standards Regulations (2007)
Waste management	· Hazardous Waste Management Regulations (2009) · Solid Waste Management Regulations (2009)

2) Environmental standards

According to the section 140(1) of the EMA, the National Environmental Standards Committee of the Tanzanian Bureau of Standards (TBS) is required to develop, review and submit proposals for environmental standards relating to: water quality, discharge of effluent, air quality, noise and vibration, subsonic vibration, ionising and other radiation, soil quality, noxious smells, light pollution, electromagnetic waves and microwaves.

Standards Act, 2009: It provides for the promotion of the standardization of specifications of commodities and services, to re-establish the TBS and to provide better provisions for the functions, management and control of the Bureau. Some of the TBS related standards are: TZS 825:2012 (Air quality-Specification), TZS 860:2006 (Municipal and industrial wastewaters – General tolerance limits for municipal and industrial wastewaters), TZS 932:2007 (Acoustics – General tolerance limits for environmental noise), TZS 972:2007 (Soil quality – Limits for soil contaminants in habitat and agriculture). Relevant specific criteria are referred to in the impact assessment described below.

3) Other related legal systems

Natural Environment Conservation

- Forest Act, 2002: It provides for the management of forests, to repeal certain laws relating to forests and for related matters. Forest reserves and Mangrove forest reserves are established based on this act.

- Wildlife Conservation Act, 2013: It provides for the conservation of wildlife and ensures protection, management and sustainable utilization of wildlife resources, habitats, ecosystems and the non-living environment supporting such resources, habitats or ecosystems. Game Reserves, Game controlled areas, corridor areas, buffer zones are established based on this Act.

Land acquisition

- Land Act, 1999: It provides for the basic law in relation to land other than the village land, the management of land, settlement of disputes and related matters. The Land Act relates to land-use planning processes and land-use management and guidance to land ownership in Tanzania.
- Village Land Act, 1999: The Village Land Act was enacted specifically for the administration and management of land in villages. Under the provisions of this Act, the village council is responsible for the management of the village land.
- Land Acquisition Act 1967: Any land acquisition that shall be done shall be guided by this law. Under the Land Acquisition Act, 1967, the President may, subject to the provisions of this Act, acquire any land for any estate or term where such land is required for any public purpose.

12.2.2 Institutional Framework for Environmental and Social Considerations in Tanzania

The Environmental Management Act 2004 establishes the institutional framework for environmental management in Tanzania. It confers the tasks of overall coordination of environmental management and provision of the central support functions to the Ministry Responsible for Environment, which is the Vice President's Office (VPO). The relevant organizations related to environmental and social considerations in this case are as follows.

Table 12.2-2 Related Organizations for Environmental and Social Considerations in Tanzania

Level	Agency	Role
Competent Sector Ministries and Agencies	Ministry of Energy (MOE)	Supervision of natural gas supply operations and facilities development by TPDC. Each sector ministry carries out its functions and duties in connection with the environment according to EMA and any other law provided that such law does not conflict with EMA. Involvement of Sector Ministries in environmental management is through a sector environment sections which have been established in each ministry to ensure that ministries comply with the EMA. The Ministry of Energy also has environmental officers.

Level	Agency	Role
Project Implementer (Operator)	Tanzania Petroleum Development Corporation (TPDC)	Project implementation, mitigation measures, monitoring of all environmental issues and supervision of contractors. Environmental officers are assigned within TPDC.
Country-level (National)	Senior Vice-President's Office (Vice President's Office) Environmental Ministers	Issue an Environmental Certificate and environmental management conditions having received project recommendation from NEMC. • The Minister can articulate policy guidelines, make regulations, guidelines, can designate any institution to perform any function. The Minister can make rules for preparation of periodic environmental plans at sector level, can make regulations prescribing the procedure and manner in which Environmental Action Plans may be prepared, adopted and implemented. • The Director of Environment coordinates environmental activities, advices the government on the law and international environmental agreements on the environment, monitor and assess activities of relevant agencies, prepares and issue State of Environment Report.
	National Environment Management Council (NEMC)	Review the project's Environmental Impact Assessment (EIA). Ensure that the project EIA is implemented according to the conditions of the EIA certificate. Recommend to the Minister Responsible for Environment to grant an EIA Certificate after the project proponent have followed all EIA process. Issue directives based on monitoring and evaluation reports.
	Ministry of Land and Human Settlements Development	Advice and monitoring all issues, which will be related with Land Acquisition and Resettlement.
	Tanzania National Roads Agency (TANROADS)	Issue permit on transporting heavy and abnormal loads such as transformers and generator engines.
	Occupational Safety and Health Authority (OSHA)	Workplace inspections. Industrial hygiene surveys. Issues guidelines, regulations and standards. Health examinations of workers, Training of workers and employers.
Regional level	Regional Secretariats	The Regional Secretariat is composed of a Regional Environmental Management Expert (REME) charged with the responsibility to advise the Local Government Authorities of that particular administrative region on matters relating to implementation and enforcement of EMA. The REME links the region with the Director of

Level	Agency	Role
		Environment.
District and ward level	District governments	Overseeing district development activities and issuing of permit. Monitoring the project implementation activities for the benefit of the municipal environment. Collaborate with the project developer to ensure that mitigation measures address adverse impacts.
	Ward Council	Planning environmental management programs within their respective wards. Reporting on environmental activities of projects within the wards. Mobilizing and capacity building of the population within the wards in regard to environmental management and protection. Implementing ward environmental management and protection programs within the ward.

Source: JICA study team

12.3 Framework for Environmental and Social Considerations in International Finance

In order to confirm the environmental and social issues are appropriately addressed by the project owner in financial appraisal, guidelines and standards have been formulated by the international financing institutions such as JICA, the World Bank, and the International Finance Corporation (IFC). The following environmental and social considerations frameworks are related to this plan (Figure 12.3-1). When formulating and implementing specific projects based on this plan, these frameworks are to be considered depending on the funding sources.

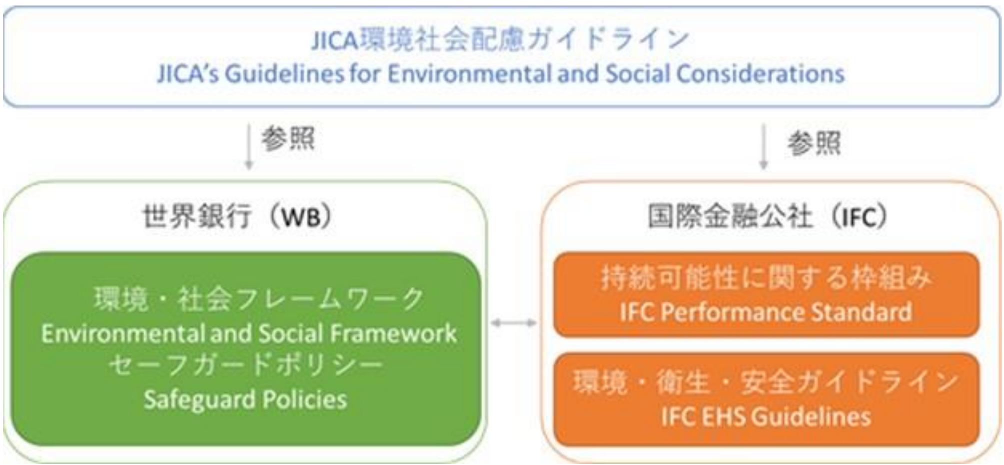


Figure 12.3-1 Framework for Environmental and Social Considerations by the World Bank, the International Finance Corporation, and JICA

In addition, ESG (Environment, Social, and Governance) investing under the United Nations Principles for Responsible Investment (UNPRI) are becoming an increasingly popular investment approach due to the emergence of global environmental and social issues, the Summit on Sustainable Development (SDGs) adopted at the United Nations Summit in 2015, and the Paris Agreement (Paris Agreement) adopted at the 21st Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC). International institutions are promoting initiatives related to ESG, affecting the way of thinking and behaviour of stakeholders of business companies. Since there is a trend to consider environmental, social, and governance (ESG) factors in investment standards in both the resource industry and infrastructure sector, following frameworks on environmental and social issues by the international financing institutions are to be considered in implementing specific project based on this plan, to manage environmental and social risks in financing projects.

12.3.1 International Finance Corporation (IFC) Sustainability Framework

The International Finance Corporation (IFC) is a member of the World Bank Group and is an international development financial institution that promotes private sector development in developing countries. The IFC Framework on Sustainability began in 1998 with the 10 Safeguard Policies, which were amended to address the private sector based on the World Bank's Environmental Guidelines, and was revised in 2012. The IFC Framework on Sustainability is also a standard for financial institutions to invest in and finance the private sector. It is also referred to by the Environmental and Social Considerations Standards of Export Credit Agencies (ECAs) and the Equator principles (EPs), which are guidelines for assessing and managing environmental and social risks associated with large-scale project financing by global private financial institutions. The IFC Framework is an internationally referenced standard for environmental and social risk management in project financing.

1） IFC Performance Standards (IFC PS)

One of the IFC's sustainability frameworks, Performance Standards (PS), is composed of the following eight items, and shows consideration for the human rights of workers and affected local people, in addition to protecting the natural environment and preventing pollution.

Table 12.3-1 Eight criteria of the IFC Performance Standards

PS1	Assessment and Management of Environmental and Social Risks and Impacts
PS2	Labour and Working Conditions
PS3	Resource Efficiency and Pollution Prevention
PS4	Community Health, Safety, and Security
PS5	Land Acquisition and Involuntary Resettlement
PS6	Biodiversity Conservation and Sustainable Management of Living Natural Resources
PS7	Indigenous Peoples
PS8	Cultural Heritage

2) IFC Environmental, Health and Safety (EHS) Guidelines

IFC's environmental, health and safety (EHS) guidelines[75] are positioned as an international guidance document that provides control and preventive measures for the three PSs of IFC: “PS2 Labour and Working Conditions”, “PS3 Resource Efficiency and Pollution Prevention,” and “PS4 Community Health, Safety, and Security.”

The EHS Guidelines include General EHS Guidelines and Industry Sector Guidelines that are generally applicable regardless of sector. Pollution control standards set forth in the EHS Guidelines are used as global standards, and are also referred to in the JICA Guidelines for Environmental and Social Considerations. In general, environmental and social considerations for each project are reviewed with reference to both the general EHS guidelines and the sector-specific EHS guidelines to which the project applies.

- General EHS Guidelines consist of EHS Guidelines for the following four areas.
  - Environment (air environment, water, water resources, noise, vibration, waste management, energy conservation, hazardous material management, soil pollution)
  - Occupational Health and Safety (Ensuring the Working Environment and Health and Safety of Workers)
  - Community health and safety (water use, fire safety, traffic safety, transport of dangerous goods, disease prevention, emergency response, etc.)
  - Construction and disposal measures (measures to be taken after construction of the project or after completion of the project)

- Sectoral EHS Guidelines: Demonstrate environmental, occupational health and safety, and community health and safety measures for projects in various industrial sectors such as oil and gas development and thermal power generation. Sectoral EHS guidelines relevant to this project include:
  - LNG facilities (EHS Guidelines for Liquefied Natural Gas (LNG) Facilities)
  - Gas-supply facilities (EHS Guidelines for Gas Distribution Systems)

12.3.2 World Bank's safeguard policy

The World Bank (IBRD/IDA) has formulated a Safeguard Policy on Environmental and Social Considerations for Loan Projects for Developing Countries, primarily for public sector projects financed by the World Bank, and consists of the following:

OP 4. 01 Environmental Assessment (Environmental Assessment)
OP 4. 04 Natural Habitats (Natural Habitats)
OP 4. 36 Forests (Forests)
OP 4. 09 Pests Control (Pest Management)
OP 4. 11 Tangible Cultural Properties (Physical Cultural Resources)
OP 4. 37 Safety (Safety of Dams) of Dams
OP 4. 12 Involuntary Resettlement (Involuntary Resettlement)

[75] The World Bank Group Environmental, Health, and Safety Guidelines

OP 4. 10 indigenous peoples (Indigenous People)
OP 7. 50 Projects on Global Hydrographic (Projects on International Waterways)
OP 7. 60 Conflict-Area Projects (Projects in Disputed Areas)

In place of the safeguard policy in operation, the World Bank launched a new Environmental and Social Framework in October 2018. The new Environmental and Social Framework consists of environmental and social standards (ESS) in 10 areas: environmental and social impact assessment, labor, resource efficiency, and pollution prevention, community health and safety, land acquisition, resettlement, ecosystems, indigenous peoples, cultural heritage, financial intermediaries, and stakeholder engagement. This framework is to be applied to projects which concept notes were approved on or after October 1, 2018, and the existing Safeguard Policy are to be applied to the previous projects.

12.3.3 JICA Environmental and Social Guideline

For contributing to sustainable development in developing countries, the inclusion of environmental and social costs in development costs and the social and institutional framework that makes such inclusion possible are crucial for sustainable development. Internalization and an institutional framework are requirements for measures regarding environmental and social considerations, and JICA is required to have suitable consideration for environmental and social impacts.

The JICA Guidelines for Environmental and Social Considerations (JICA Guidelines, April 2010) were formulated based on the JICA's belief that establishing a framework for internalization and institution is an "environmental and social consideration." The purpose of these Guidelines is to encourage partner countries to implement appropriate environmental and social considerations by indicating the responsibilities and procedures for environmental and social considerations undertaken by the JICA and the requirements required by partner countries, and to ensure appropriate implementation of JICA's support and verification of environmental and social considerations. The JICA guidelines are applied to preparatory surveys for PPP infrastructure financing projects and feasibility studies and demonstration projects for Japanese SMEs Overseas Business Development.

Environmental and social considerations in JICA's cooperation scheme means considering environmental impacts including air, water, soil, ecosystem, flora, and fauna, as well as social impacts including involuntary resettlement, respect for the human rights of indigenous people, and so on. and other social impacts.

JICA Guidelines covers following five cooperation schemes. If projects are implemented using these schemes, they are required to be conducted in accordance with JICA Guidelines.

- Loan aid
- Grant Aid (except through international organizations)
- Preliminary survey conducted by JICA on grant aid provided by the Ministry of Foreign

Affairs

- Technical Cooperation for Development Planning
- Technical Cooperation Projects

The basic principles of these guidelines is as follows.

- While project proponents etc. bear the ultimate responsibility for the environmental and social considerations of projects, JICA supports and examines appropriate environmental and social considerations undertaken by project proponents etc. to avoid or minimize development projects' impacts on the environment and local communities, and to prevent the occurrence of unacceptable adverse impacts.
- JICA has clear requirements regarding environmental and social considerations, which project proponents etc. must meet. JICA provides project proponents etc. with support in order to facilitate the achievement of these requirements through the preparation and implementation of cooperation projects. JICA examines undertakings by project proponents etc. in accordance with the requirements, and makes adequate decisions regarding environmental and social considerations on the basis of examination results.

The JICA Guidelines stipulate guidelines for environmental and social considerations in JICA's cooperation projects, including processes for environmental and social considerations, categorization of projects, items to be considered for environmental and social considerations, disclosure of information, consultation with stakeholders, and decision-making by JICA.

When implementing technical cooperation projects for formulation of this plan as well as any specific projects through JICA's cooperation scheme based on this plan, such projects are required to be implemented in accordance with JICA Guidelines.

12.3.4 Major Gaps between Tanzanian legislation and JICA Guidelines

There are several differences between JICA Guidelines and the Tanzanian legal framework for environmental and social considerations.

Table 12.3-2 Major Differences in EIA Related Laws and Regulations

JICA environmental guidelines	Relevant laws in Tanzania	Main gaps and Actions to close gap
・ Projects must not involve significant conversion or significant degradation of critical natural habitats and critical forests. ・ Whenever feasible, projects are sited on lands already converted (excluding any lands considered to have been converted in anticipation of the project). JICA does not support projects involving the significant conversion of natural habitats unless there are no feasible alternatives for the project and its siting, and comprehensive analysis demonstrates that overall benefits from the project substantially outweigh the environmental costs. If the environmental assessment indicates that a project would significantly convert or degrade natural habitats, the project includes mitigation measures acceptable to JICA. Such mitigation measures include, as appropriate, minimizing habitat loss (e.g., strategic habitat retention and post-development restoration) and establishing and maintaining an ecologically similar protected area. JICA accepts other forms of mitigation measures only when they are technically justified.	・ The Environmental Management Act 2004 stipulates that the Minister responsible for Environmental Protected Areas by considering flora and fauna, special feature, the interests of the local communities and accordance with international society. (Article 47) ・ Under the National Policies for National Parks in Tanzania, 1994, although, the primary objectives are the protection and inheritance of natural resources (Article3.1), permission of all projects in National Parks is granted based on Environmental Impact Assessment, which clarify positive and negative impacts.	Under the domestic law in Tanzania, even within National Parks, project permission can be granted depending on the EIA result. It is not prescribed as for the necessity of analysing if the economic benefits outweigh environmental costs. Counter Measure: It is desirable to avoid, and this project does not plan, construction within National Parks. The plant and satellites under the project are small and will be sited on lands already converted such as the Kinyerezi Energy Complex and industrial parks at various cities.
・ Confirm that projects comply with the laws or standards related to the environment and local communities in the central and local governments of host countries; it also confirms that projects conform to those governments' policies and plans on the environment and local communities.	There is Environmental Impact Assessment System provided by EMA.	There is no difference in particular.
・ For projects with a potentially large environmental impact, sufficient consultations with local stakeholders, such as local residents, must be conducted via disclosure of information at an early stage, at which time alternatives for project plans may be examined. The outcome of such consultations must be incorporated into the contents of project plans. ・ In preparing EIA reports, consultations with stakeholders, such as local residents, must take place after sufficient information has been disclosed. Records of such consultations must be prepared. ・ Consultations with relevant stakeholders, such as local residents, should take place if necessary throughout the preparation and implementation stages of a project. Holding consultations is highly desirable, especially when the items to be considered in the EIA are being selected, and when the draft report is being prepared;	Residents are given the opportunity to participate from the screening stage of the project. A public hearing will be held by NEMC during the review period of the EIA report, the EIA report will be published, and comments will be accepted verbally and in writing. In addition, the EIA report is stored as an official document at NEMC and can be viewed when needed. (Environmental Impact Assessment and Audit Regulations, 2005)	There is no difference in particular.

・ The impacts to be assessed with regard to environmental and social considerations include impacts on human health and safety, as well as on the natural environment, that are transmitted through air, water, soil, waste, accidents, water usage, climate change, ecosystems, fauna and flora, including trans-boundary or global scale impacts. These also include social impacts, including migration of population and involuntary resettlement, local economy such as employment and livelihood, utilization of land and local resources, social institutions such as social capital and local decision-making institutions, existing social infrastructures and services, vulnerable social groups such as poor and indigenous peoples, equality of benefits and losses and equality in the development process, gender, children's rights, cultural heritage, local conflicts of interest, infectious diseases such as HIV/AIDS, and working conditions including occupational safety. ・ In addition to the direct and immediate impacts of projects, their derivative, secondary, and cumulative impacts as well as the impacts of projects that are indivisible from the project are also to be examined and assessed to a reasonable extent. It is also desirable that the impacts that can occur at any time throughout the project cycle should be considered throughout the life cycle of the project.	Criteria for screening: ・The project should not be located in the following areas and should not affect the following areas. a) National park b) Wetlands c) Productive farmland d) Important archaeological, historical and cultural sites e) Areas protected by law f) Areas inhabited by rare or endangered species g) Unique or prominent area h) Mountains, on or near hills on steep slopes i) Lake and near the lakeside j) Development of resources important to vulnerable groups k) Densely populated areas where further development can cause significant environmental problems Areas with active industrial activities and their vicinity l) Major groundwater recharge areas or areas important for water surface runoff ・The project should not produce the following results a) Policies to encourage increased agricultural subsidies to impact or mitigate the negative impact b) Major changes in land tenure c) Changes in water use through irrigation, drainage or dams, changes in fisheries ・ The project does not have the following effects a) Adverse effects on socioeconomics b) Land deterioration c) Water pollution d) Air pollution e) Adverse effects on wildlife and their habitats f) Adverse effects on climate and water cycle g) By-products, residues or wastes that require treatment and disposal by methods not regulated by existing authorities ・ The project should not cause public concern due to changes. The guideline is as follows. a) Primarily, are the early effects good or harmful? b) What is the magnitude of the impact on the number of affected people and wildlife species? c) How strong is the impact? d) What about the duration of the impact?	There is no difference in particular.

JICA environmental guidelines	Relevant laws in Tanzania	Main gaps and Actions to close gap
	e) Is there a cumulative effect of the impact? f) Do those effects lead to political debate? g) Does it bring major economic, ecological and social costs? h) Does the impact vary by social organization and gender? i) Is there an international impact of the proposed project?	
・Any adverse impacts that a project may have on indigenous peoples are to be avoided when feasible by exploring all viable alternatives. If avoidance is not possible even after such examination, effective measures for indigenous peoples must be taken to minimize the impacts and to compensate for the losses. ・Measures for the affected indigenous peoples must be prepared as an Indigenous Peoples Plan (IPP), which may constitute as a part of other documents for environmental and social considerations, and must be made public in compliance with the relevant laws and ordinances of the host country.	There are no particular provisions for indigenous peoples in Tanzania. In Tanzania, the expression of "indigenous people" is not used and they are included in "vulnerable people". EMA states that projects should not affect the resources that are important to the vulnerable. People.	Tanzania's domestic law does not have a legal system that is specific to indigenous people, but it is dealt with in consideration of the vulnerable people. If vulnerable people corresponding to World Bank OP4.10 exist in the project area, attempt to avoid the impact, and if the impact is unavoidable, create an Indigenous People Plan (IPP).
・ EIA reports (which may be referred to differently in different systems) must be written in the official language or in a language widely used in the country in which the project is to be implemented. For explanations, documents must be formulated in a language and manner, and that are understandable to the affected local people.	EISs (EIA reports) etc. should be formulated in languages understandable to stakeholders.	There is no difference in particular.
・ In principle, host countries etc. disclose information about the environmental and social considerations of their projects. Assist project proponents etc.as needed. ・ Encourage host countries etc. to disclose and present information about environmental and social considerations to local stakeholders. ・ EIA reports are required to be made available to the local residents of the country in which the project is to be implemented. The EISs are required to be available at all times for perusal by project stakeholders such as local residents and copying must be permitted. ・ In principle, host countries etc. consult with local stakeholders to a reasonable extent. Assist host countries as needed.	・ From screening step of project, participation opportunities are provided. During EIS review period, public consultation is held and EIS is made public and comments are received verbally and in writing. ・ Also, EIS is stored as official document by NEMC and available for perusal when needed.	There is no difference in particular.
・ Confirm monitoring results through host countries etc. to verify environmental and social considerations are implemented surely. The information necessary for monitoring confirmation must be supplied by host countries etc. by appropriate means, including in writing. ・ Also, disclose the results of monitoring conducted by host countries etc. on its website to the extent that they are made public in host countries etc.	NEMC shall conduct environmental assessment. Project proponents should store monitoring data and formulate annual report and report actual result compared with original plan to NEMC. When negative impacts were occurred, appropriate mitigation measures shall be planned and implemented.	There is no regulation regarding monitoring result. Counter Measure: The monitoring results will be disclosed on the website.

Table 12.3-3 Major Differences in Land Acquisition and Relocation Laws and Regulations

JICA Guidelines and WB Safeguard policy	Relevant laws in Tanzania	Main gaps and Actions to close gap
Involuntary resettlement and loss of means of livelihood are to be avoided when feasible by exploring all viable alternatives. (JICA GL)	No specific provisions on avoiding involuntary resettlement and loss of means of livelihood although these can come from Environmental and Social Impact Assessment (ESIA)	Avoiding involuntary resettlement is not mentioned in Tanzania land laws. Counter Measure: Attempt to avoid involuntary resettlement. The plant and satellites under the project are small and will be sited on lands already converted such as the Kinyerezi Energy Complex and industrial parks at various cities.
When population displacement is unavoidable, effective measures to minimize impact and to compensate for losses should be taken. (JICA GL)	• When displacement is unavoidable, compensation will be given as follows (Land Act, 1999 – Cap 113, Part II Section 3 (1) (g) , Section 34 and 156) • Market value of unexhausted improvement[76], disturbance allowance, transport allowance, accommodation allowance and loss of profits, although depreciated replacement value is given and valuation is often not done properly because some aspects that need to be included are not taken into account – for example, using market values is sometimes ignored and information to affected persons is not sufficiently provided	• Full replacement value (market value) plus transaction costs are not mentioned in Tanzania laws. • Measures to minimize impacts are not explicit in Tanzania laws. Counter Measure: The replacement cost and mitigation measures to minimize the impact of the relocation will be considered when necessary.
People who must be resettled involuntarily and people whose means of livelihood will be hindered or lost must be sufficiently compensated and supported, so that they can improve or at least restore their standard of living, income opportunities and production levels to pre-project levels. (JICA GL)	Livelihood restoration is not addressed although, sometimes done through provision of alternative affected social services- for example, providing an alternative health facility or a school are cases in point.	Livelihood restoration is not explicit in Tanzania laws. Counter Measure: If involuntary resettlement cannot be avoided, consider measures to restore livelihood.
Compensation must be based on the full replacement cost as much as possible. (JICA GL)	Market values but usually in practice provide with depreciated replacement values (although the law does not direct the use of depreciated values)	Full replacement cost not paid. Counter Measure: Payment will be made at the replacement cost as much as possible.

[76] Land Act, 1999 interprets unexhausted improvement as anything or any quality permanently attached to the land directly resulting from the expenditure of capital or labour by an occupier or any person acting in his behalf and increasing the productive capacity, the utility, the sustainability of its environmental quality and includes trees standing crops and growing produce whether of an agricultural or horticulture nature. This condition has been amended by the Land (Amendment Act), 2004 by replacing Subsection 8 and 9 of the Land Act 1999 to allow for sale land without unexhausted improvements. For development purposes or as joint venture.

JICA Guidelines and WB Safeguard policy	Relevant laws in Tanzania	Main gaps and Actions to close gap
Compensation and other kinds of assistance must be provided prior to displacement.	Compensation must be paid before relocation. (Land Acquisition Act, 1967 (15- (1)) and Land Act 1999- Cap 113). Tanzania allows the government to own the acquired land before paying the compensation, but current practice is to make an effort to pay the compensation before owning the land.	There is no gap.
For projects that entail large-scale involuntary resettlement, resettlement action plans must be prepared and made available to the public. (JICA GL)	For large scale involuntary resettlement compensation must be provided (Land Acquisition Act 1967 Part II Section 11 and Land Cap 113, Part II Section 3 (1) (g))	Tanzania Law does not consider Resettlement Action Plan as mandatory. Counter Measure: If involuntary resettlement cannot be avoided, a resettlement action plan will be prepared.
In preparing a resettlement action plan, consultations must be held with the affected people and their communities based on sufficient information made available to them in advance.	There are scanty provisions related to consultation and disclosure in Tanzanian law. The notice, under the Land Acquisition Act, informs land owners about the President’s need to acquire their land, and their right to give objections. The Land Act allows displaced persons to fill in forms requiring that their land be valued, and giving their own opinion as to what their assets are worth. Since resettlement is not provided for legally, there are no provisions about informing the displaced persons about their options and rights; nor are they offered choice among feasible resettlement alternatives.	The provisions in WB OP 4.12 requiring consultation and disclosure have no equivalent provisions in Tanzanian law. Counter Measure: Where necessary, provide detailed and effective consultation and information disclosure with affected people.
When consultations are held, explanations must be given in a form, manner, and language that are understandable to the affected people.	Under the Land Acquisition Act, land owners must be informed about the President’s need to acquire their land, and their right to give objections. The Land Act allows displaced persons to fill in forms (in Kiswahili) requiring that their land be valued, and giving their own opinion as to what their assets are worth.	There are no provisions about informing the displaced persons about their options and rights; nor are they offered choice among feasible resettlement alternatives. Counter Measure: Consider detailed and effective consultation and information sharing with affected persons in a language and format that they can understand.

JICA Guidelines and WB Safeguard policy	Relevant laws in Tanzania	Main gaps and Actions to close gap
Appropriate participation of affected people must be promoted in planning, implementation, and monitoring of resettlement action plans.	Consultation with wide range of project stakeholders including individuals or groups affected by the project, either positively or negatively, as well as the host community are regularly held as a procedure towards resettlement exercise. Tanzania's law does not provide for the consideration of vulnerable groups.	Tanzanian law does not make provisions requiring the government to pay special attention to vulnerable groups in the administration of compensation despite the consultations. Counter Measure: Consider appropriate and effective participation of affected persons during the planning, implementation and monitoring of resettlement plans. Also, consider the socially vulnerable groups.
Appropriate and accessible grievance mechanisms must be established for the people and their communities to be affected by unwilling resettlement and losing livelihoods. (JICA GL)	Tanzania land law provides a mechanism for dealing with grievances including lodging complaints to the courts (Land Acquisition Act 1967, Section 13 (1) and (2) and Land Act, Cap 113. Part XIII Section 167 (1))	Tanzania grievance mechanism is not easily accessible to affected persons. Counter Measure: In the event of involuntary resettlement, the accessibility of the affected people will be considered in the grievance mechanism.
Eligibility of benefits includes, the PAPs who have formal legal rights to land (including customary and traditional land rights recognized under law), the PAPs who don't have formal legal rights to land at the time of census but have a claim to such land or assets and the PAPs who have no recognizable legal right to the land they are occupying. (WB OP4.12 Para.15)	Eligibility of benefits includes, the PAPs who have formal legal rights to land (including customary and traditional land rights recognized under law), the PAPs who don't have formal legal rights to land at the time of valuation but have invested on land will be eligible for compensation of assets but not land (recognized as tenants) Land Act Cap 133	Tanzania Law does not recognize encroachers. Counter Measure: Eligibility of benefits includes; ・ the PAPs who have formal legal rights to land, ・ the PAPs who don't have formal legal rights to land at the time of census but have a claim to such land or assets, ・ the PAPs who have no recognizable legal right to the land they are occupying.
Provide support for the transition period (between displacement and livelihood restoration). (WB OP4.12 Para.6)	-	The law is silent about provision of support during transition and for livelihood restoration. Counter Measure: Support for the transition period will be considered.

Source: JICA study team

12.4 Baseline for the Target Area

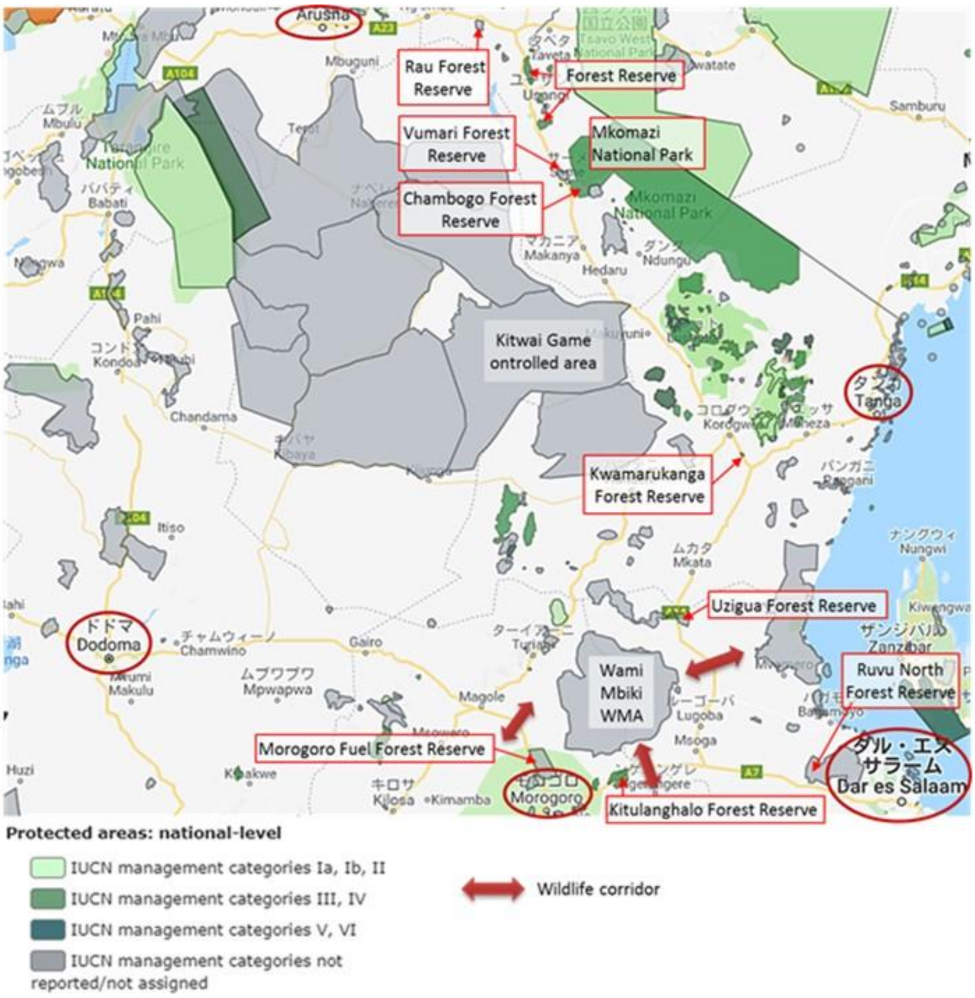
12.4.1 Natural Environment

1) Protected area

The protected areas and wildlife corridors in northeastern Tanzania are as shown in Figure 12.4-1.

The A 7 highway from Dar es Salaam to Morogoro, which is a potential route for transporting natural gas, passes through Kitulanghalo Forest Reserve, and the A 14 highway that runs north from Dar es Salam to Tanga and Arusha passes through Uzigua Forest Reserve, and Kwamarukanga Forest Reserve on its way to Arusha. Morogoro Fuel Forest Reserve is located on the east side of the highway B127 from Morogoro to Dodoma.

As indicated by red arrows in Figure 12.4-1, there are three areas where an existing highway crosses wildlife corridors. These are considered to be corridors for wildlife to move between Wami Mbiki Wildlife Management Area (WMA) and Mikumi National Park in the southwest, and Selous Game Reserve in the south, and Sadani National Park in the northeast. Elephants, buffaloes, greater kudu, hartebeest, and waterbuck may move in these corridors.[77]



Source: Prepared by JICA research team based on data such as BirdLife International, CI, and UNEP data and Wildlife Corridors in Tanzania, 2009

Figure 12.4-1 Protected Area and Wildlife Movement Pathway in Northeast Tanzania

77 Wildlife Corridors in Tanzania, Tanzania Wildlife Research Institute (TAWIRI), 2009

The Kinyerezi energy complex in Dar es Salaam as a starting point of natural gas transportation to Dodoma is not located in the protected area. The nearest protected area, Pugu Forest Reserve (Figure 12.4-2), is about 4 km away from the energy complex area. There are no protected areas in the north and south of the complex area, where potential transportation routes from the Energy Complex to Pugu Station and to the A7 highway to Morogoro are located.

Source: prepared by a JICA study team based on data from BirdLife International, CI, UNEP, etc.

Figure 12.4-2 Protected Area in Dar es Salaam

Similarly, in Dodoma, the three satellite candidate areas are not located in the protected area (Figure 12.4-3).

Source: prepared by JICA study team based on data such as BirdLife International, CI, UNEP, etc.

Figure 12.4-3 Protected Area in Dodoma

2) Ecosystem and rivers

According to the land-cover map of the northeastern part of Tanzania shown in Figure 12.4-4, both the highway from Dar es Salaam to Morogoro and to Tanga are mainly passing through bushland and cultivated bushland except for forest reserve area. The route from Tanga to Arusha and the route from Morogoro to Dodoma are mainly passing through bushland, cultivated bushland, and grains and other crops.

Major rivers crossing these highways are Ruvu River in the section from Dar es Salaam to Morogoro, and Wami River in the section from Morogoro to Dodoma. From Dar es Salaam to Tanga and Arusha, Wami, Mligazi, Msangazi and Pangani rivers are crossing.

In Dar es Salaam, where mini-LNG plants are expected to be installed, most of vegetation and habitats have been lost or replaced due to urban development such as housing land development, social infrastructure development, and park development. Except for small mammals, birds, reptiles, and amphibians living along the Msimbazi River and its estuaries, no large wildlife is found in the centre of the city. Common animals include birds, butterflies, batters, ants.

Major vegetation includes coastal shrubs, Miombo (Brachystegia) forests, coastal wetlands, and mangrove forests. The mangrove forest is located near the mouth of the Msimbazi River and is far away from the potential target sites of the mini-LNG Plants. Although urban vegetation is evergreen, natural vegetation is scattered.

Dodoma is rather dry with an annual rainfall between 550 mm and 600 mm, while in Dar es Salaam it is between 800 mm and 1,300 mm. Dodoma is located in part of the East Africa Central Highlands and is a plateau with an altitude of about 400 m. Because of these natural conditions, Dodoma has very few trees and grass vegetation, and is characterized by open grassland and bushy vegetation where grasses grow sparsely. In addition, the fertility of soil is low due to wind and erosion.

Forest degradation and wood resource use for fuel

The total forest area in Tanzania is 48 million ha, of which only 7 % are classified as forests (mangroves, coastal forests, humid montane forest and plantations). Some 28 million ha (33 %) of the lands in Tanzania are under legal protection (protected forests and wildlife reserves). The annual loss of wood was estimated at 62.3 million m^3 as shown in Table below. The consumption exceeds the sustainable supply, causing an annual wood deficit of 19.5 million m^3. It is estimated that the average demand for wood at 1.39 m^3/year/capita while the annual allowable cut (the sustainable supply) was estimated at 0.95 m^3/year/capita. In terms of GHG emissions from deforestation, the Forest Reference Emission Level (FREL) for Tanzania is estimated at 58.4 million ton-CO_2e/year. This is about 0.92% of the total amount of 6.3 billion ton-CO_2 stock in the forested.

Table 12.4-1 Wood balance in Tanzania

Supply and losses	Unit	2013
Supply		
Gross increment of all trees in Tanzania mainland	million m^3/yr	83.7
Legally available wood (AAC plus recoverable deadwood)	million m^3/ yr	42.8
Losses:		
Household wood demand (0.96 m^3/capita)	million m^3/ yr	-43.0
Industrial and household wood demand (0.05 m^3/capita. FAOSTAT 2014)	million m^3/ yr	-2.3
LULC change analysis (1995 vs 2010 maps) on FW: (-372816 ha/a * 40 m^3/ ha; 0.33 m^3/capita)	million m^3/ yr	-14.9
Import-export balance (charcoal, lumber and logs; 0.00 m^3/capita)	million m^3/ yr	-0.1
Illegal felling for charcoal/lumber mfg, trading (0.05 m^3/capita)	million m^3/ yr	-2.0
Total losses	**Million m^3/ yr**	-62.3
Wood Balance	million m^3/ yr	-19.5

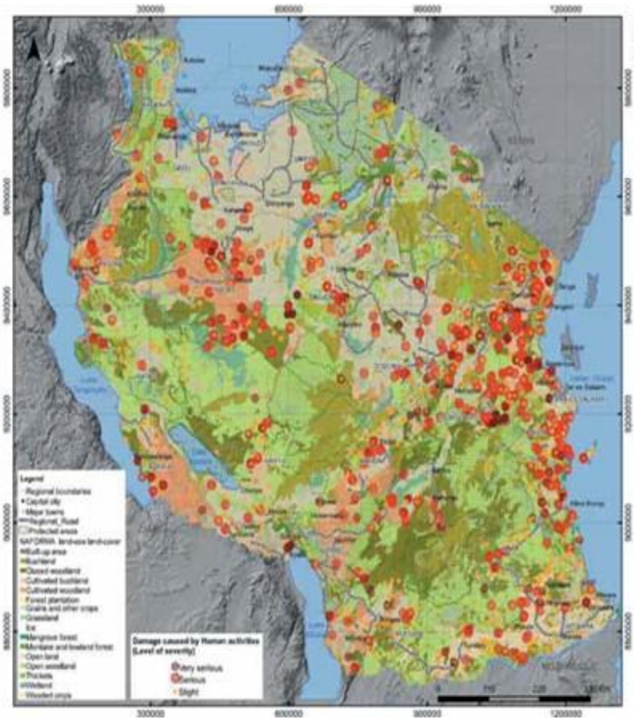
Source: National Forest Monitoring and Assessment (NAFORMA) of Tanzania, Ministry of Natural Resources and Tourism (MNRT), Tanzania Forest Services (TFS) Agency, 2015

Table 12.4-2 Forest cover and its amount in the regions

	Region	Area of the region (ha)	Percentage of the land covered by forest and wood land in the region (%)	Total volume of forest wood (million m3)	Number of trees (trees/ha)
1	Morogoro	6,886,883	63.6	376.2	1,268
2	Dodoma	4,183,192	32.8	117.8	685
3	Tanga	2,810,612	47.9	115.2	1,576
4	Arusha	3,822,918	43.5	58.3	693
5	Kilimanjaro	1,250,496	48.6	47.9	579

Source: NAFORMA of Tanzania, Ministry of Natural Resources and Tourism, TFS, 2015

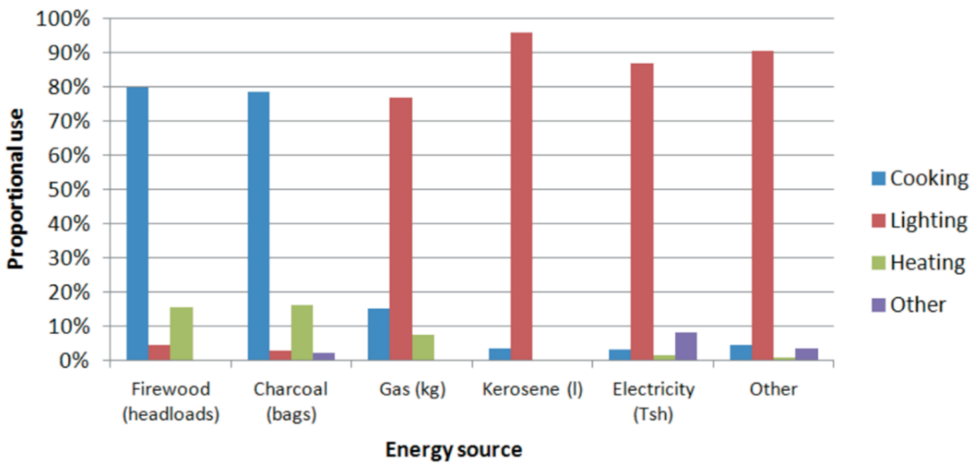
Figure 12.4-4 shows damage caused by human activities and severity of damage. Most of the damages caused by human activities were recorded in the Eastern and Western zones, probably due to the proximity to urban and/or city areas. The damage may be the result of the combined effect of charcoal production for the urban markets, overharvesting of firewood and other wood products as well as expanding shifting cultivation.



Source: National Forest Monitoring and Assessment (NAFORMA) of Tanzania, Ministry of Natural Resources and Tourism (MNRT), Tanzania Forest Services (TFS) Agency, 2015

Figure 12.4-4 Level severity of damage to forests and woodlands caused by human activities

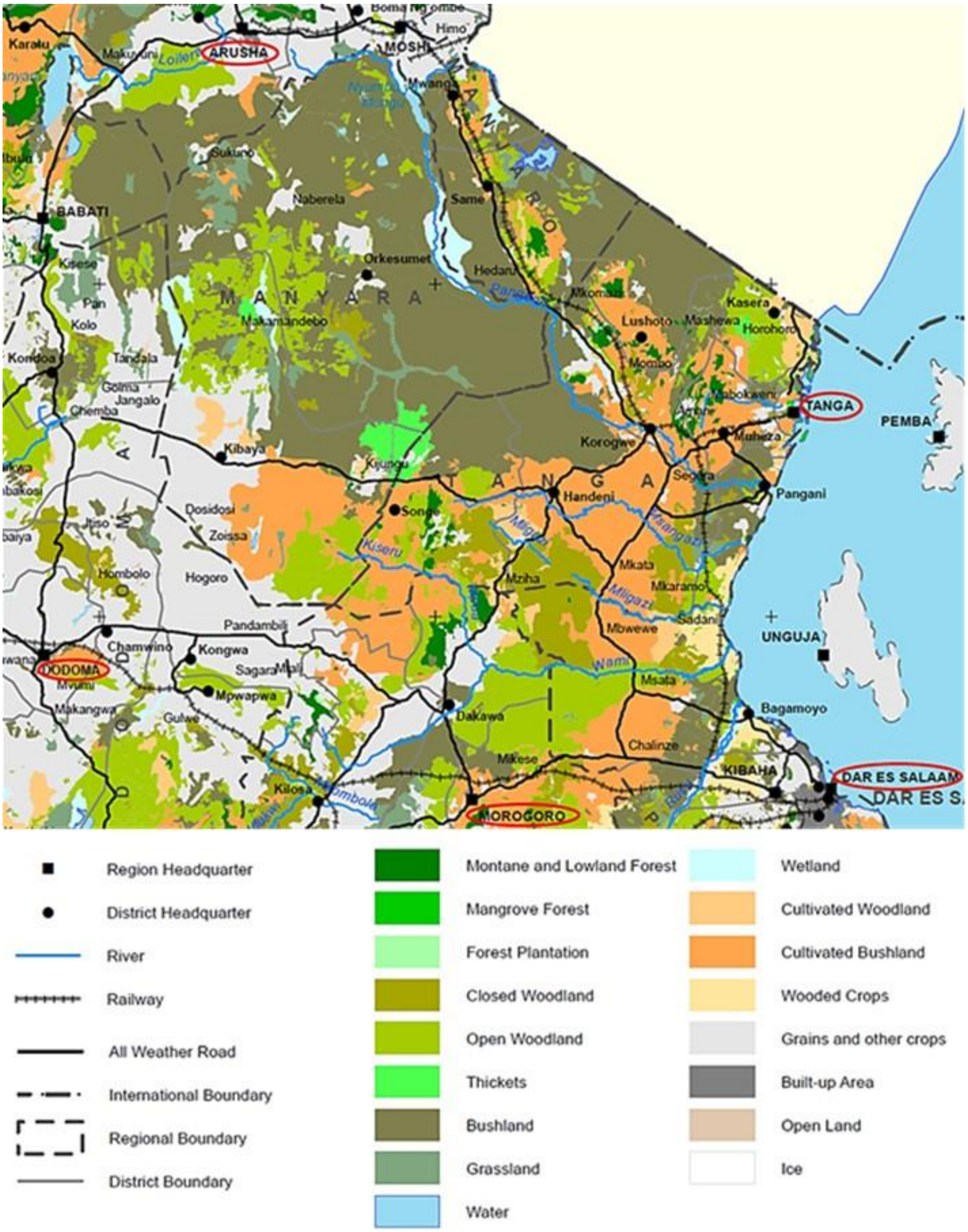
Figure 12.4-5 summarises the sources of energy for the households. The results show that firewood and charcoal are predominantly used for cooking whereas kerosene, electricity and others are mainly used for lighting.



Source: NAFORMA, MNRT, 2015

Figure 12.4-5 Sources and uses of energy at household level

As shown the above figures, people seems to depend on wood resources (firewood, charcoal) for cooking and the overuse of wood resources is contributing to annual wood deficit.



Source: Ministry of Natural Resources and Tourism 2011

Figure 12.4-6 Land Cover Map in Northeast Tanzania

2) Air pollution

According to the 2nd State of Environment Report (VPO, 2014), air pollution problem is evident in terms of urban road congestion in cities (Dar es Salaam, Mwanza, Arusha, Mbeya and Tanga) where the number of vehicles required to meet demand exceed the capacity as the increasing vehicles do not keep pace with the expansion of road network. For example, Dar es Salaam has 50% to 60% of the vehicles in Tanzania on its roads whereas these roads are said to have been designed to support population up to two million people and the actual carrying capacity of the roads is estimated to be 15,000 vehicles while there are about 190,000 vehicles travelling on the same infrastructure on daily basis.

The average hourly sulphur oxide concentration (SOx) for Dar es Salaam ranges from 127 to 1,385ug/m3. These values are above the recommended WHO guidelines. The average hourly nitrogen oxide (NOx) concentration ranges from 18 to 53 ug/m^3 which are below WHO guideline value of 200 ug/m^3. The average hourly suspended particulate (SPM) ranges from 98 to 1,161 ug/m^3, exceeding the recommended value of 230 ug/m^3 by WHO.

Table 12.4-3 Estimated annual emission loads of air pollutants in Dar es Salaam city

Air pollution source	SPM		NOx (t/yr)	SOx (t/yr)	Benzene (t/yr)
	PM10 (t/yr)	PM2.5 (t/yr)			
Vehicle	442	398	1,250	2,851	436
Industry	55,647	50,082	1,215	453	-

Source: Dar es Salaam city Environment Outlook 2011 (Vice President's Office)

Table 12.4-4 IFC EHS guideline valus and emission loads of air pollutants in Dar es Salaam

Air Pollution Source	Dar es Salaam	IFC EHS Guideline Value
SOx	1 hour value 127～1,385ug/m^3	1 hour value 350 ug/m^3
NOx	1 hour value 18～53ug/m^3	10minute value 200 ug/m^3
SPM	1 hour value 98～1,161 ug/m^3	1 hour value 230 ug/m^3

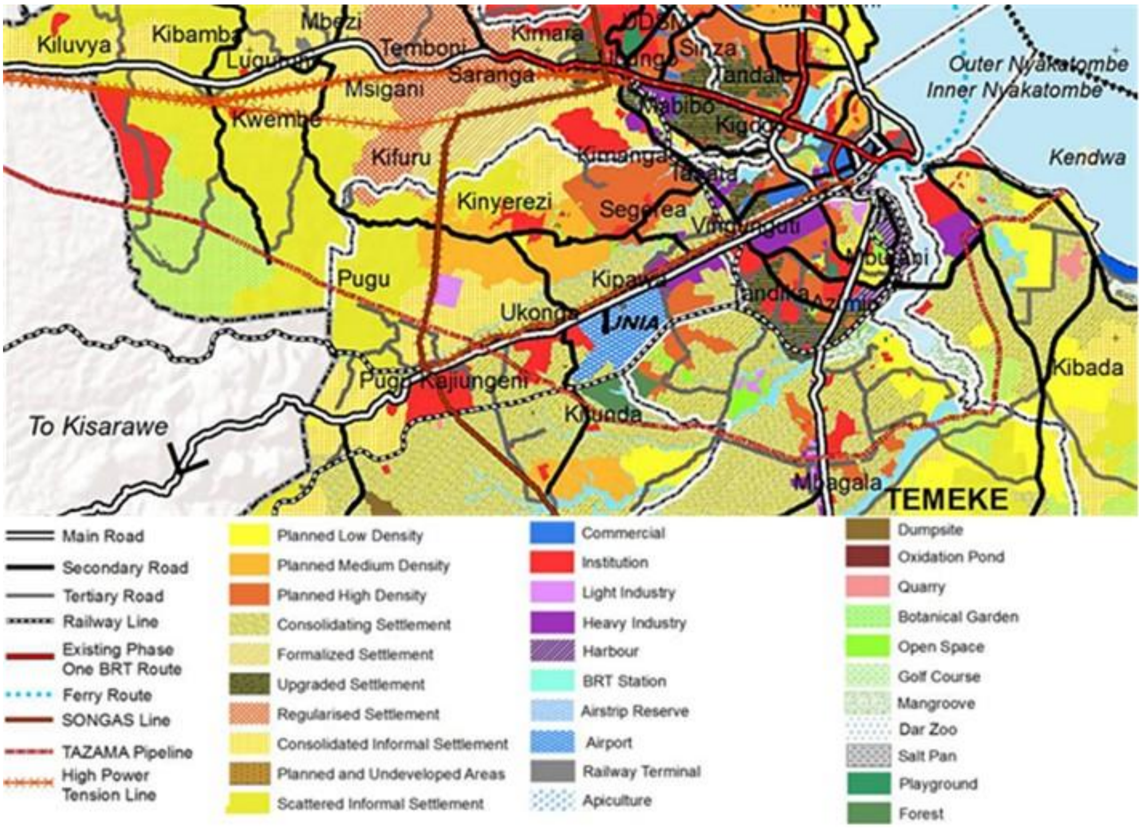
Source：IFC EHS Guideline, Dar es Salaam city Environment Outlook 2011

12.4.2 Social environment

1) Land use

The installation of the mini-LNG plant or the CNG-plant is assumed to be within the Kinyerezi Energy Complex in Dar es Salaam. Since natural gas-treatment facility and two power plants have already been installed in this area, and the area is classified as an industrial area in the Dar es Salaam Urban Master Plan 2030 (Figure 12.4-11), the location is consistent with existing land use

(Figure 12.4-7) and future land use plans. Land use along the route from the Energy Complex to the main road is currently informal settlements in the south and medium dense planned area in the north (Figure 12.4-7), and there are residential houses in the vicinity of the site (Figure 12.4-8 and 12.4-10).



Source: Dar es Salaam City Master Plan 2016-2036

Figure 12.4-7 Current land use in Dar es Salaam

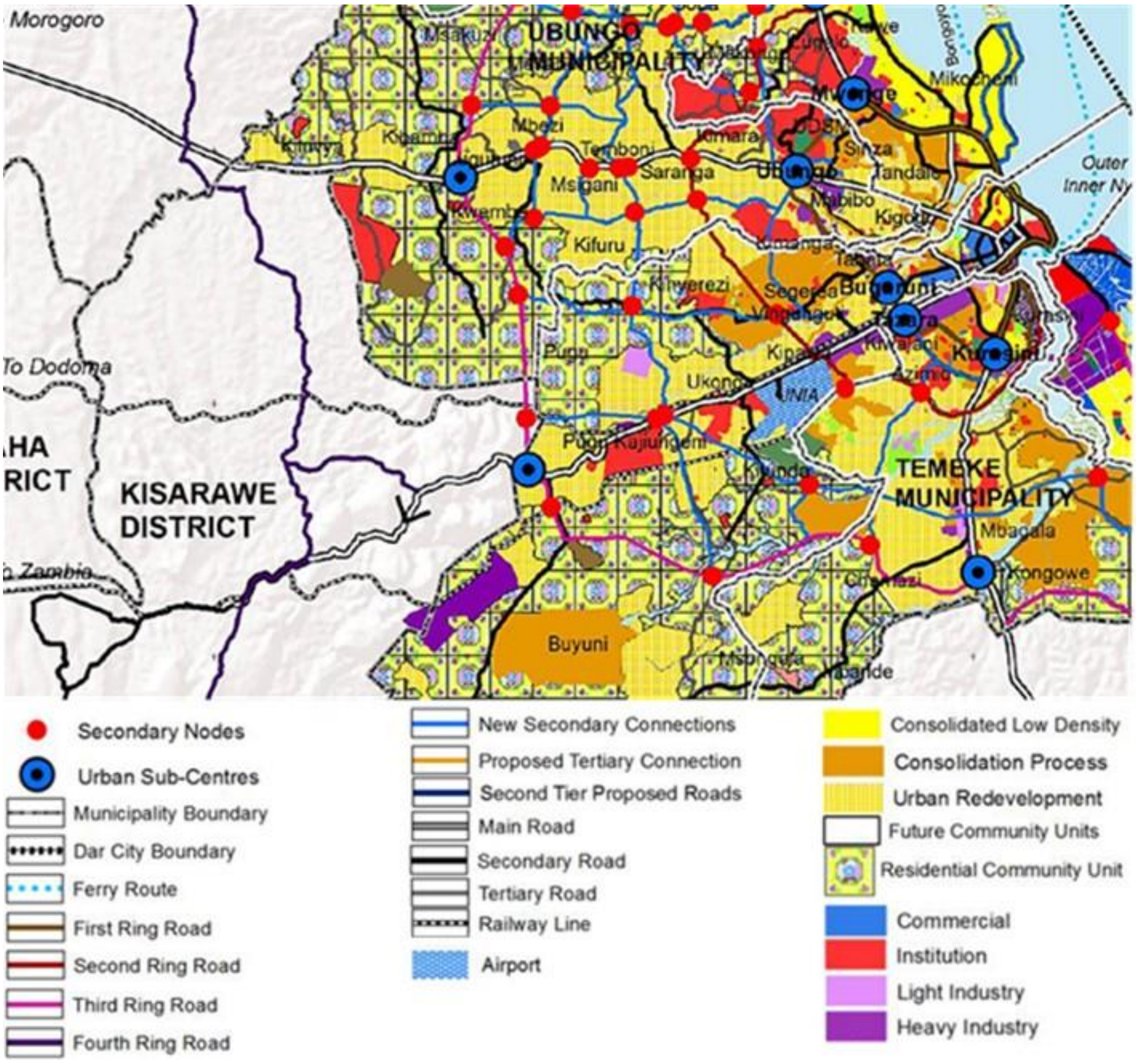

Figure 12.4-8 Kinyerezi energy complex: Access Road from North-western Boundary

Figure 12.4-9 Kinyerezi energy complex: Western boundary

Figure 12.4-10 Kinyerezi energy complex: Southern boundary

In future land use plan, the north and west of the Energy Complex are residential communities for commuters in the city, and the south is an urban redevelopment area (Figure 12.4-10).

In the future, the population of Dar es Salaam is expected increase much more, and the population around the Energy Complex would also increase. There are schools and medical facilities along the access road to the A2 highway to Morogoro in the north.



Source: Dar es Salaam City Master Plan 2016-2036

Figure 12.4-11 Land use plan and Road development plan in Dar es Salaam

Potential areas for installation of satellite facilities in Dodoma are as shown in Figure 12.4-11. In the future land use plan, Satellite A (New Government City) is in the government area, Satellite B (Zuzu power station) is in the industrial area, the Satellite C (Iyumbu Satellite centre) is in the residential area.

The current status of each satellite's candidate area is shown in Figure 12.4-12, 12.4-13 and 12.4-14.

Figure 12.4-12 Satellite A: New Government City

Figure 12.4-13 Satellite C: Iyumbu Satellite centre

As shown in Figure 12.4-14 below, an existing small power plant and a new substation can be seen in Zuzu Power Station area. TANESCO has secured land around these areas, and there were few houses seen.

Figure 12.4-14 Satellite B: Zuzu power Station (left) and substation (right)

2) Road

Natural gas could be transported in the form of LNG or CNG by vehicle using existing highways from Dar es Salaam to Morogoro, Dodoma, Tanga, and Arusha. The access road from the Kinyerezi Energy Complex in Dar es Salaam to the existing highways are expected to be as shown in Figure 12.4-15, through the access road extending north from the energy Complex to the A7 highway to Morogoro. This road is paved, and is also positioned as a fourth ring road in the Dar es Salaam City Master Plan 2030. On the other hand, if natural gas is transported from Pugu Station to Morogoro and Dodoma by railway, the pink route shown in Figure 12.4-15 needs to be repaired, paved, or new roads need to be developed in order to access the highway in the south of the Complex. Of these routes, the eastern route is close to the route planned as the secondary connecting road in the Dar es Salaam City Master Plan 2030. If this road is developed, it is expected to be accessible from the Energy Complex to the Pugu station. Nevertheless, housing is concentrated in the vicinity of the Energy Complex. Msimbazi River also passes through this southern area.

Source: prepared by JICA study team from Google earth

Figure 12.4-15 Potential transportation route from Kinyerezi Energy Complex to the highways

3) Cultural heritage

Tanzania has abundant cultural heritage resources over a wide range of periods from the fresh new generation about 4 million years ago to the present. As a government agency, the Ministry of Natural Resources and Tourism's Cultural Heritage Department is responsible for protecting, preserving and managing these cultural heritage resources.

Table 12.4-5 National Cultural Heritage Sites in Dar es Salaam, Dodoma and Tanga

Site name	Region	District	Type	Age	Managing
Kunduchi Ruins	Dar es Salaam	Kinondoni Northeast	Swahili Cultural Site	20th century	Central government
Magomeni Museum			Museum	13th century	Central government
Kondoa Irangi Rock Art	Dodoma	Kondoa	Rock art	5000 years ago	Central government
Ambon Caves	Tanga	Tanga Urban	Geological site	Unknown	Central government
Tongoni Ruins			Swahili Cultural Site	14th century	Central government

Source: Department of Cultural Heritage, Ministry of Natural Resources and Tourism

Antiquities Act of 1964 (Act No. 10 of 1964 Cap 550) and its Amendments (Antiquities (Amendment) Act of the 1979 (Act No. Of 1979 20) and related provisions (Rules and Regulations of 1981, 1991, 1995 and 2002) legally protect cultural heritage sites. National cultural heritage sites in Dar es Salaam, in Dodoma, and in Tanga are as shown in Table 12.4-5.

4) Indigenous people

Tanzania is a multi-ethnic nation consisting of more than 120 ethnic groups, but indigenous peoples have not been formally identified, and there is no particular legal framework for indigenous people in Tanzania. According to a report by the World Bank in 2012, Hadzabe and Barabaig were considered as indigenous peoples in that study. Many of these ethnic groups live in northern Tanzania. The Hadzabe are moving hunters and live in the south of Ngorongoro Conservation Area (NCA) in the west of Lake of Eyasi. The Barabaig live livestock farming while moving and live abundantly in the Hanang District of Manyara Region.[78]

12.5 Scoping, Survey on Environmental and Social Considerations and Assessment of Impact

1) Scoping

Regarding the domestic supply of natural gas in Tanzania, the three transport scenarios, use of pipeline, CNG, or LNG which are generally adopted for natural gas transportation, are scoped as shown in Table 12.5-1, based on the above baseline information.

[78] Draft TASAF III Indigenous Peoples Policy Framework, 2012

Table 12.5-1 Scoping for three transportation modes of natural gas

Category	No.	Item		Potential Impact			Description
				Pipeline	CNG	LNG	
Pollution	1	Air Pollution	Construction Phase	✓	✓	✓	Construction Phase: Exhaust gas from construction vehicles and heavy equipment may increase during construction works. Dust emissions may be generated by site excavation and movement of earth materials for pipeline route, mini-LNG, CNG facility areas. Operation Phase: Gas pipeline and distribution system may generate leaks, principally consisting methane (CH_4). Emission from flaring, venting, and fugitive sources may result from gas processing facilities. CNG or LNG transporting trucks generate air emission from fuel combustion.
			Operation Phase	✓	✓	✓	
	2	Water Pollution	Construction Phase	✓	✓	✓	Construction Phase: Discharges to water bodies may increase during construction works and land reclamations. Operation Phase: Wastewater may contain dissolved hydrocarbons and other contaminants. Storm water from the facility site may be contaminated as a result of spills.
			Operation Phase	✓	✓	✓	
	3	Soil Contamination	Construction Phase	✓	✓	✓	Construction & Operation Phase: If adequate measures are not taken to prevent soil contamination by leaked materials, products and chemicals used during the construction and operation of the natural gas processing facility, soil contamination may occur.
			Operation Phase	✓	✓	✓	
	4	Waste	Construction Phase	✓	✓	✓	Construction Phase: Construction wastes may be generated during construction works. Operation Phase: General waste is expected to be generated. Hazardous waste such as hydrocarbon or chemical contained waste may be generated from the gas processing facilities, or maintenance activities.
			Operation Phase	✓	✓	✓	
	5	Noise and Vibration	Construction Phase	✓	✓	✓	Construction Phase: Noise and vibration may occur due to the operation of earth moving and excavation equipment, and materials transport. Operation Phase: Natural gas processing operation and gas product transportation by rail or road may increase noise and vibration.
			Operation Phase		✓	✓	
	6	Ground Subsidence	Construction Phase				Construction & Operation Phase: Large scale groundwater pumping is not expected.

Category	No.	Item		Potential Impact			Description
				Pipeline	CNG	LNG	
			Operation Phase				
	7	Odour	Construction Phase	✓	✓	✓	Construction & Operation Phase: Construction work and transportation of gas product may increase exhaust gas. Waste generation may cause odor if not properly managed.
			Operation Phase	✓	✓	✓	
	8	Bottom sediment	Construction Phase	✓	✓	✓	Construction Phase: Sediment and erosion from construction activities and storm water runoff may increase turbidity and affect bottom characteristics. Operation Phase: Since vegetation along the gas pipeline route is necessary to be removed, soil erosion along the gas pipeline route may occur affecting nearby water bodies.
			Operation Phase	✓			
Natural Environment	9	Protected Areas	Construction Phase	✓			Construction & Operation Phase: Mini-LNG and CNG facilities, satellite facilities are not expected to be located in the protected areas. Gas pipeline may be passing through or nearby the protected areas.
			Operation Phase	✓			
	10	Ecosystem	Construction Phase	✓			Construction Phase: Mini-LNG and CNG facilities, satellite facilities are expected to be located in urban area. Gas pipeline may be passing through or nearby habitat areas, wildlife corridors, and rivers. Land reclamation and establishment of gas pipeline may create temporary or permanent habitat alternation depending on the characteristics of existing vegetation. It could also cause habitat fragmentation and loss of wildlife habitat. Operation phase: Since the main road to be used for Gas product transportation is passing wildlife corridors and forest reserves, wildlife may be affected if transportation operation is not well managed.
			Operation Phase	✓	✓	✓	
	11	Hydrology	Construction Phase	✓			Construction Phase: Land reclamation and construction work for the gas pipeline nearby water body may cause hydrological changes. Mini-LNG and CNG facilities, satellite facilities are expected to be located in urban area and require limited area. Operation Phase: Topographical change and vegetation removal by gas pipeline installation
			Operation Phase	✓			

Category	No.	Item		Potential Impact			Description
				Pipeline	CNG	LNG	
							may cause hydrological change.
	12	Topography and Geographical Features	Construction Phase	✓	✓	✓	Construction Phase: Land reclamation for facility installation may change tomography and geographical features. Mini-LNG and CNG facilities, satellite facilities are expected to require relatively small area. Operation phase: Soil erosion along the gas pipeline route may occur affecting topographic features.
			Operation Phase	✓			
Social Environment	13	Involuntary Resettlement and Land Acquisition	Construction Phase	✓	✓	✓	Construction Phase: Although at the moment exact siting of the facilities are not known, depending on the location, involuntary resettlement and land acquisition may occur associated with the facility development. Such impact should be avoided, mitigated and compensated properly. Wayleave width of 12" gas pipeline is 30m and a large area around 1,500 ha is necessary to be acquired for installing gas pipeline between Dar es Salaam and Dodoma, while relatively small area is required for Mini-LNG, CNG and satellite facilities.
			Operation Phase				
	14	Poverty (poor people)	Construction Phase	✓			Construction phase: Due to the large area of land to be acquired for installing gas pipeline, it would affect livelihood of poor people because of the physical or economical relocation. Mini-LNG and CNG facilities, satellite facilities do not require large land area and little impact is expected for installing such facilities, however, construction activities may affect livelihood and daily life of poor people living around the construction site. Operation Phase: Since siting plan will be developed during the course of master plan formulation, it is not known if there is any impact on such people at the moment. Construction work and gas supply operation may bring associated employment opportunity to the poor.
			Operation Phase				
	15	Ethnic minority and Indigenous Peoples	Construction Phase	✓	✓	✓	Construction & Operation Phase: There is no official identification of indigenous people in Tanzania although a concept of tribe does exist. Since exact siting plan is not known, it is not known if there is any impact on such people at the moment. Hadzabe and Baragaig are mainly in northern Tanzania and they are usually moving with their livestock or for hunting. If such people
			Operation Phase	✓	✓	✓	

Category	No.	Item		Potential Impact			Description
				Pipeline	CNG	LNG	
							come close to the gas pipeline or gas transportation route, their activity may be affected.
	16	Local Economy (Employment, Livelihood etc.)	Construction Phase	✓	✓	✓	Construction & Operation Phase: Facility development and promotion of gas utilization may increase employment opportunity and enhance local economy. Construction vehicle and gas product transportation vehicle traffic may have some impact on existing road or railway operation depending of its planned volume and frequency. It may cause impact on local economic activities. Land acquisition for installing gas pipeline and associated relocation may have impact on livelihood of affected local people. Once operation starts, gas as clean modern fuel becomes available in local markets providing stable energy platform replacing firewood, charcoal, coal and oil.
			Operation Phase	✓	✓	✓	
	17	Land Use and Utilization of Local Resources	Construction Phase	✓			Construction & Operation Phase: Local land use planning may be facilitated by the master plan formulation. During the course of master plan formulation, local urban development plans/land use plans are to be considered.
			Operation Phase	✓			
	18	Water Use	Construction Phase	✓	✓	✓	Construction Phase: Construction work may cause increase in turbidity of the water resource for local people. Operation Phase: Water use by gas facilities is very little and it is negligible. (The LNG plant is designed to use air-cooling.)
			Operation Phase				
	19	Existing Social Infrastructure and Services	Construction Phase	✓	✓	✓	Construction Phase: Due to the influx of construction workers although the size of expected workforce is rather small, the capacity of the existing social service infrastructure such as health care facility may be pressurized to some extent. Construction work may cause traffic congestions and traffic accidents. Operation Phase: Gas product transportation may have some impact on existing road or railway operation depending of its planned volume and frequency. Due to the installation of gas pipeline, the existing infrastructure such as water wells may be affected depending on the
			Operation Phase		✓	✓	

Category	No.	Item		Potential Impact			Description
				Pipeline	CNG	LNG	
							route.
	20	Social Institutions such as Local Decision Making Institutions	Construction Phase	✓	✓	✓	Construction & Operation Phase: Schools and dispensary are located near the potential transportation route from Kinyerezi Energy Complex to the main road, construction vehicle and gas transportation vehicle traffic may have some impact on safe access to such social institutions and decision making institutions of local centres. Establishment of gas pipeline may affect the way to such institutions as well. Once the operations starts, hospitals, schools and other social institutions will greatly benefit from easy, clean and efficient fuel gas system for preparation of meals and hot water.
			Operation Phase	✓	✓	✓	
	21	Misdistribution of Benefit and Damage	Construction Phase				Construction & Operation Phase: Areas which cannot receive benefit from gas supply operation may exist. Changes of land use due to installation of gas pipeline may have some impact on local people's livelihood.
			Operation Phase				
	22	Local Conflict of Interest	Construction Phase				Construction & Operation Phase: Conflict between benefited group and non-benefited group within or around the planned area may occur such as employment opportunity.
			Operation Phase				
	23	Cultural Heritage	Construction Phase	✓			Construction & Operation Phase: Since Mini-LNG plant or CNG plant is expected to be located within Kinyerezi Energy Complex, which is an industrial area, no impact on cultural heritage is expected from these plants. Satellite facilities are expected to be located in urban area considering land use plan and little impact is expected from satellites. Since installation of gas pipeline involves large scale land acquisition, land use change or construction works may displace or demolish cultural sites. Facility development should avoid such sites.
			Operation Phase				
	24	Landscape	Construction Phase	✓	✓	✓	Construction Phase: Depending on location of construction works, use of heavy equipment and construction vehicles may give impact on landscape. Operation Phase: Establishment of gas facilities and gas pipeline may have some impact on landscape. Mini-LNG plant or CNG plant is
			Operation Phase	✓	✓	✓	

Category	No.	Item		Potential Impact			Description
				Pipeline	CNG	LNG	
							expected to be located within Kinyerezi Energy Complex which is an industrial area, and it would not have significant impact on landscape since power plants are already existing.
	25	Gender	Construction Phase	✓	✓	✓	Construction & Operation Phase: Promotion of domestic gas utilization may benefit local people life including women's living environment. A dispensary is located near the potential transportation route from Kinyerezi Energy Complex to the main road, construction vehicle and gas transportation vehicle traffic may have some impact on women to go to dispensary especially with elders and small children. Establishment of gas pipeline may affect the way to dispensary and hospital as well. Once operation starts, gas as clean modern fuel will replace firewood and charcoal and will dramatically improve domestic air quality to reduce lung diseases, shorten cooking time, and ease fuel collection and carrying in which women are mainly engaged.
			Operation Phase	✓	✓	✓	
	26	Right of Children	Construction Phase	✓	✓	✓	Construction & Operation Phase: Promotion of domestic gas utilization may improve local people life including children's living environment such as less fire wood collection and smoke in the house. Schools are located near the potential transportation route from Kinyerezi Energy Complex to the main road, construction vehicle and gas transportation vehicle traffic may have some impact on school children. Establishment of gas pipeline may affect the way to school as well.
			Operation Phase	✓	✓	✓	
	27	Infectious Diseases (such as HIV/AIDS)	Construction Phase	✓	✓	✓	Construction Phase: Workforce influx may cause increase of infectious diseases such as HIV/AIDS although the expected size is rather small. Operation phase: Since the size of workforce operating gas facilities is very small, increase of infectious diseases due to workforce influx is not expected.
			Operation Phase				
	28	Public Health	Construction Phase	✓	✓	✓	Construction Phase: If waste and swage of the work area are not properly managed, deterioration of public health around project sites may occur. Operation Phase: If waste and wastewater are
			Operation Phase	✓	✓	✓	

Category	No.	Item		Potential Impact			Description
				Pipeline	CNG	LNG	
							not properly managed, public heath may be affected. Once operation starts, gas will replace firewood and charcoal and will dramatically improve domestic air quality to reduce lung diseases.
Others	29	Accidents and Safety	Construction Phase	✓	✓	✓	Construction Phase: Accidents may occur during construction works. Exposure of workers to harmful gases and explosive gas may occur. Operation Phase: Storage, transport of LNG or CNG may result in leaks or accidental release from tanks, pipes, and pumps. The storage and transport of LNG or CNG poses a risk of fire and explosion as well as leakage from gas pipeline.
			Operation Phase	✓	✓	✓	
	30	Cross-Border Impact, Global Warming	Construction Phase				Construction: Necessary construction workforce is not expected to be large scale for mini-LNG and CNG facilities, satellite facility, and gas pipeline. Operation Phase: Natural gas facility may emit CH_4 due to leakage. Transportation of gas product involves CO2 emissions from vehicles. Introduction of natural gas will contribute to preservation of forests replacing firewood and charcoal, and also reduction of GHG emissions with its high efficiency as well as preventing potential use of more carbon rich fuels such as oil and coal.
			Operation Phase	✓	✓	✓	

3) Impact Assessment

Outcome of the assessment of potential impacts on environmental and social considerations by implementation of this project is shown as below.

Table 12.5-2 Impact Assessment of Domestic Natural Gas Transport Modes

Category	No.	Items		Potential Impact			Description
				Pipeline	CNG	LNG	
Pollution	1	Air Pollution	Construction Phase	B-	B-	B-	Construction Phase: Exhaust gas from construction vehicles and heavy equipment may increase during construction works. Dust emissions may be generated by site excavation
			Operation	B-	B-	B-	

Category	No.	Items		Potential Impact			Description
				Pipeline	CNG	LNG	
			Phase				and movement of earth materials for pipeline route, mini-LNG, CNG facility areas. Operation Phase: Gas pipeline and distribution system may generate leaks, principally consisting methane (CH_4). Emission from flaring, venting, and fugitive sources may result from gas processing facilities. CNG or LNG transporting trucks generate air emission from fuel combustion.
	2	Water Pollution	Construction Phase	B-	B-	B-	Construction Phase: Discharges to water bodies may increase during construction works and land reclamations. Operation Phase: Wastewater may contain dissolved hydrocarbons and other contaminants. Storm water from the facility site may be contaminated as a result of spills.
			Operation Phase	B-	B-	B-	
	3	Soil Contamination	Construction Phase	B-	B-	B-	Construction & Operation Phase: If adequate measures are not taken to prevent soil contamination by leaked materials, products and chemicals used during the construction and operation of the natural gas processing facility, soil contamination may occur.
			Operation Phase	B-	B-	B-	
	4	Waste	Construction Phase	B-	B-	B-	Construction Phase: Construction wastes may be generated during construction works. Operation Phase: General waste is expected to be generated. Hazardous waste such as hydrocarbon or chemical contained waste may be generated from the gas processing facilities, or maintenance activities.
			Operation Phase	B-	B-	B-	
	5	Noise and Vibration	Construction Phase	B-	B-	B-	Construction Phase: Noise and vibration may occur due to the operation of earth moving and excavation equipment, and materials transport. Operation Phase: Natural gas processing operation and gas product transportation by rail or road may increase noise and vibration.
			Operation Phase	D	B-	B-	
	6	Ground Subsidence	Construction Phase	D	D	D	Construction & Operation Phase: Large scale groundwater pumping is not expected.
			Operation Phase	D	D	D	
	7	Odor	Construction Phase	B-	B-	B-	Construction & Operation Phase: Construction work and transportation of gas product may increase exhaust gas. Waste generation may cause odor if not properly managed.
			Operation	B-	B-	B-	

Category	No.	Items		Potential Impact			Description
				Pipeline	CNG	LNG	
			Phase				
	8	Bottom sediment	Construction Phase	B-	B-	B-	Construction Phase: Sediment and erosion from construction activities and storm water runoff may increase turbidity and affect bottom characteristics. Operation Phase: Since vegetation along the gas pipeline route is necessary to be removed, soil erosion along the gas pipeline route may occur affecting nearby water bodies.
			Operation Phase	B-	D	D	
Natural Environment	9	Protected Areas	Construction Phase	B-	D	D	Construction & Operation Phase: Mini-LNG and CNG facilities, satellite facilities are not expected to be located in the protected areas. Gas pipeline may be passing through or nearby the protected areas.
			Operation Phase	B-	D	D	
	10	Ecosystem	Construction Phase	B-	D	D	Construction Phase: Mini-LNG and CNG facilities, satellite facilities are expected to be located in urban area. Gas pipeline may be passing through or nearby habitat areas, wildlife corridors, and rivers. Land reclamation and establishment of gas pipeline may create temporary or permanent habitat alternation depending on the characteristics of existing vegetation. It could also cause habitat fragmentation and loss of wildlife habitat. Operation phase: Since the main road to be used for Gas product transportation is passing wildlife corridors and forest reserves, wildlife may be affected if transportation operation is not well managed.
			Operation Phase	B-	B-	B-	
	11	Hydrology	Construction Phase	B-	D	D	Construction Phase: Land reclamation and construction work for the gas pipeline nearby water body may cause hydrological changes. Mini-LNG and CNG facilities, satellite facilities are expected to be located in urban area and require limited area. Operation Phase: Topographical change and vegetation removal by gas pipeline installation may cause hydrological change.
			Operation Phase	B-	D	D	
	12	Topography and Geographical Features	Construction Phase	B-	B-	B-	Construction Phase: Land reclamation for facility installation may change topography and geographical features. Mini-LNG and CNG facilities, satellite facilities are expected to require rather small area.
			Operation Phase	B-	D	D	

Category	No.	Items		Potential Impact: Pipeline	Potential Impact: CNG	Potential Impact: LNG	Description
							Operation phase: Soil erosion along the gas pipeline route may occur affecting topographic features.
Social Environment	13	Involuntary Resettlement and Land Acquisition	Construction Phase	A-	C	C	Construction Phase: Although at the moment exact siting of the facilities are not known, depending on the location, involuntary resettlement and land acquisition may occur associated with the facility development. Such impact should be avoided, mitigated and compensated properly. Wayleave width of 12" gas pipeline is 30m and a large area around 1,500 ha is necessary to be acquired for installing gas pipeline between Dar es Salaam and Dodoma, while rather small area is required for Mini-LNG and CNG facilities, satellite facilities.
			Operation Phase	D	D	D	
	14	Poverty (poor people)	Construction Phase	B-	D	D	Construction phase: Due to the large area of land to be acquired for installing gas pipeline, it would affect livelihood of poor people because of the physical or economical relocation. Mini-LNG and CNG facilities, satellite facilities do not require large land area and little impact is expected for installing such facilities. Operation Phase: Since siting plan will be developed during the course of master plan formulation, it is not known if there is any impact on such people at the moment. Construction work and gas supply operation may bring associated employment opportunity to the poor.
			Operation Phase	D	D	D	
	15	Ethnic minority and Indigenous Peoples	Construction Phase	C	C	C	Construction & Operation Phase: There is no official identification of indigenous people in Tanzania although a concept of tribe does exist. Since exact siting plan is not known, it is not known if there is any impact on such people at the moment. Hadzabe and Baragaig are mainly in northern Tanzania and they are usually moving with their livestock or for hunting. If such people come close to the gas pipeline or gas transportation route, their activity may be affected.
			Operation Phase	C	C	C	
	16	Local Economy (Employment, Livelihood etc.)	Construction Phase	B±	B±	B±	Construction & Operation Phase: Facility development and promotion of gas utilization may increase employment opportunity and enhance local economy. Construction vehicle and gas product
			Operation Phase	A+	A+	A+	

Category	No.	Items		Potential Impact			Description
				Pipeline	CNG	LNG	
							transportation vehicle traffic may have some impact on existing road or railway operation depending of its planned volume and frequency. It may cause impact on local economic activities. Land acquisition for installing gas pipeline and associated relocation may have impact on livelihood of affected local people. Once operation starts, gas as clean modern fuel becomes available in local markets providing stable energy platform replacing firewood, charcoal, coal and oil.
	17	Land Use and Utilization of Local Resources	Construction Phase	B-	D	D	Construction & Operation Phase: Local land use planning may be facilitated by the master plan formulation. During the course of master plan formulation, local urban development plans/land use plans are to be considered.
			Operation Phase	B-	D	D	
	18	Water Use	Construction Phase	B-	B-	B-	Construction Phase: Construction work may cause increase in turbidity of the water resource for local people. Operation Phase: Water use by gas facilities are very little and it is negligible. (The LNG plant is designed to use air-cooling.)
			Operation Phase	D	D	D	
	19	Existing Social Infrastructure and Services	Construction Phase	B-	B-	B-	Construction Phase: Due to the influx of construction workers although the size of expected workforce is rather small, the capacity of the existing social service infrastructure such as health care facility may be pressurized to some extent. Construction work may cause traffic congestions and traffic accidents. Operation Phase: Gas product transportation may have some impact on existing road or railway operation depending of its planned volume and frequency. Due to the installation of gas pipeline, the existing infrastructure such as water wells may be affected depending on the route.
			Operation Phase	C	B-	B-	
	20	Social Institutions such as Local Decision Making Institutions	Construction Phase	B-	B-	B-	Construction & Operation Phase: Schools and dispensary are located near the potential transportation route from Kinyerezi Energy Complex to the main road, construction vehicle and gas transportation vehicle traffic may have some impact on safe access to such social institutions and decision making institutions of local centres. Establishment of gas pipeline may
			Operation Phase	A+	A+	A+	

Category	No.	Items		Potential Impact			Description
				Pipeline	CNG	LNG	
							affect the way to such institutions as well. Once the operations starts, hospitals, schools and other social institutions will greatly benefit from easy, clean and efficient fuel gas system for preparation of meals and hot water.
	21	Misdistribution of Benefit and Damage	Construction Phase	C	C	C	Construction & Operation Phase: Areas which cannot receive benefit from gas supply operation may exist. Changes of land use due to installation of gas pipeline may have some impact on local people's livelihood. Support for supply of LPG should be promoted simultaneously.
			Operation Phase	C	C	C	
	22	Local Conflict of Interest	Construction Phase	C	C	C	Construction & Operation Phase: Conflict between benefited group and non-benefited group within or around the planned area may occur such as employment opportunity. Support for supply of LPG should be promoted simultaneously.
			Operation Phase	C	C	C	
	23	Cultural Heritage	Construction Phase	C	D	D	Construction & Operation Phase: Since Mini-LNG plant or CNG plant is expected to be located within Kinyerezi Energy Complex, which is an industrial area, no impact on cultural heritage is expected from these plants. Satellite facilities are expected to be located in urban area considering land use plan and little impact is expected from satellites. Since installation of gas pipeline involves large scale land acquisition, land use change or construction works may displace or demolish cultural sites. Facility development should avoid such sites.
			Operation Phase	C	D	D	
	24	Landscape	Construction Phase	B-	B-	B-	Construction Phase: Depending on location of construction works, use of heavy equipment and construction vehicles may give impact on landscape. Operation Phase: Establishment of gas facilities and gas pipeline may have some impact on landscape. Mini-LNG plant or CNG plant is expected to be located within Kinyerezi Energy Complex which is an industrial area, and it would not have significant impact on landscape since power plants are already existing.
			Operation Phase	B-	D	D	
	25	Gender	Construction Phase	B-	B-	B-	Construction & Operation Phase: Promotion of domestic gas utilization may benefit local people

Category	No.	Items		Potential Impact			Description
				Pipeline	CNG	LNG	
			Operation Phase	A+	A+	A+	life including women's living environment. A dispensary is located near the potential transportation route from Kinyerezi Energy Complex to the main road, construction vehicle and gas transportation vehicle traffic may have some impact on women to go to dispensary especially with elders and small children. Establishment of gas pipeline may affect the way to dispensary and hospital as well. Once operation starts, gas as clean modern fuel will replace firewood and charcoal and will dramatically improve domestic air quality to reduce lung diseases, shorten cooking time, and ease fuel collection and carrying in which women are mainly engaged.
	26	Right of Children	Construction Phase	B-	B-	B-	Construction and Operation Phase: Promotion of domestic gas utilization may improve local people life including children's living environment such as less fire wood collection and smoke in the house. Schools are located near the potential transportation route from Kinyerezi Energy Complex to the main road, construction vehicle and gas transportation vehicle traffic may have some impact on school children. Establishment of gas pipeline may affect the way to school as well.
			Operation Phase	B+	B±	B±	
	27	Infectious Diseases (such as HIV/AIDS)	Construction Phase	B-	B-	B-	Construction Phase: Workforce influx may cause increase of infectious diseases such as HIV/AIDS although the expected size is rather small. Operation phase: Since the size of workforce operating gas facilities is expected to be very small, increase of infectious diseases due to workforce influx is not expected.
			Operation Phase	D	D	D	
	28	Public Health	Construction Phase	B-	B-	B-	Construction Phase: If waste and swage of the work area are not properly managed, deterioration of public health around project sites may occur. Operation Phase: If waste and wastewater are not properly managed, public heath may be affected. Once operation starts, gas will replace firewood and charcoal and will dramatically improve domestic air quality to reduce lung diseases.
			Operation Phase	A+	A+	A+	
Ot he	29	Accidents and	Construction	B-	B-	B-	Construction Phase: Accidents may occur during

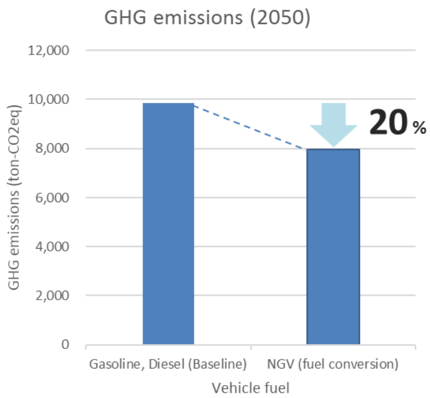
Category	No.	Items		Potential Impact			Description
				Pipeline	CNG	LNG	
		Safety	Phase				construction works. Exposure of workers to harmful gases and explosive gas may occur.
			Operation Phase	B-	B-	B-	Operation Phase: Storage, transport of LNG or CNG may result in leaks or accidental release from tanks, pipes, and pumps. The storage and transport of LNG or CNG poses a risk of fire and explosion as well as leakage from gas pipeline.
	30	Cross-Border Impact, Global Warning	Construction Phase	D	D	D	Construction: Necessary construction workforce is not expected to be large scale for mini-LNG and CNG facilities, satellite facility, and gas pipeline.
			Operation Phase	A+	A+	A+	Operation Phase: Natural gas facility may emit CH_4 due to leakage. Transportation of gas product involves CO_2 emissions from vehicles. Introduction of natural gas will contribute to preservation of forests replacing firewood and charcoal, and also reduction of GHG emissions with its high efficiency as well as preventing potential use of more carbon rich fuels such as oil and coal.

A+/- : Significant positive/negative impact is expected.
B+/- : Some positive/negative impact is expected.
C : Extent of impact is unknown at this stage (Extent of impact may become clear as study progresses).
D: No impact is expected (except tentative impacts to be managed by future detailed construction plan)
: Construction is not involved. Gas transportation component means "transportation vehicle" such as LNG rail tank car and LNG Tank Truck.

4) Survey on Environmental and Social Considerations

Outcome of the survey on the environmental and social consideration is as follows.

Natural Environment and Eco system	When natural gas is transported by vehicle in the form of LNG or CNG, it is expected to be transported through the existing highway as described above, and therefore, no significant influence on the protected area is expected. However, some part of the potential natural gas transportation route (existing highways) cross forest reserves and wildlife corridors, there are possibilities of wildlife strike if operation of transportation vehicle at night is expected. If a gas pipeline is installed from Dar es Salaam to Dodoma, it would pass through forest reserves and wildlife corridors as the existing highways, which may cause impact on such areas such as soil erosion due to vegetation removal along the route, obstruction to wildlife movements etc. In both Dar es Salaam and Dodoma, mini-LNG plant, satellite facilities, and other associated facilities are expected to be developed in urban areas (or planned urban areas), and they seem to have little impact on the natural ecosystem.
River	Major rivers crossing these highways are Ruvu River in the section from Dar es Salaam to Morogoro, and Wami River in the section from Morogoro to Dodoma. From Dar es Salaam to Tanga and Arusha, Wami, Mligazi, Msangazi and Pangani rivers are crossing. The

	possibility of flooding in the rainy season is to be considered in these river crossing area. If a gas pipeline is installed from Dar es Salaam to Dodoma, it could also cross a river as this, and a countermeasure for construction may be necessary.
Air Pollution	Temporary deterioration of air pollution may be anticipated during the construction phase with increased emissions by construction machines. If natural gas vehicles (NGVs) are introduced successfully, it would contribute to reduce the emission loads of air pollutants such as NOx and SOx as well as GHG emissions from vehicles (Figure 12.4-7), resulting in improvement of air quality in cities in Tanzania.  Source: JICA study team Figure 12.5-1 Estimation of GHG emissions reduction by fuel conversion to natural gas
Water Pollution	In the construction phase, storm water discharged from the project site may affect the quality of surface water in the neighbouring areas. Water pollution in such case can be avoided designing the drainage system to properly remove sediments and contaminated materials.
Soil Contamination	Proper prevention measures should be implemented against potential oil leakage from heavy vehicles in accordance with construction plan prepared in prior to commencement of construction.
Noise and Vibration	In the construction phase, noise and vibration may occur in the neighbouring areas due to operation of heavy machines and vehicles for material transport. Noise and vibration may be reduced by limiting construction operation only in day time and suspending during night. In the operation phase noise and vibration may increase to some extent in the areas along the gas transport route by vehicles.
Land Use	Since natural gas transportation routes for Virtual pipeline would use existing highways between cities, transportation of natural gas by the Virtual pipeline is not expected to have significant impact on land use. If natural gas is transported from Pugu Station to Morogoro and Dodoma by railway, the pink route shown in Figure 12.4-15 needs to be repaired, paved, or new roads need to be developed in order to access the highway in the south of the Complex. Housing is concentrated in the vicinity of the Energy Complex, and the development of access roads to the south may require land acquisition and the relocation of residents.
	<u>Potential location of each satellite</u> • Satellite A is in the new government city area. There is a need to locate satellite facilities in coordination with development plans in government areas, there are likely to be sufficient places where the establishment of satellite facilities may be

<table>
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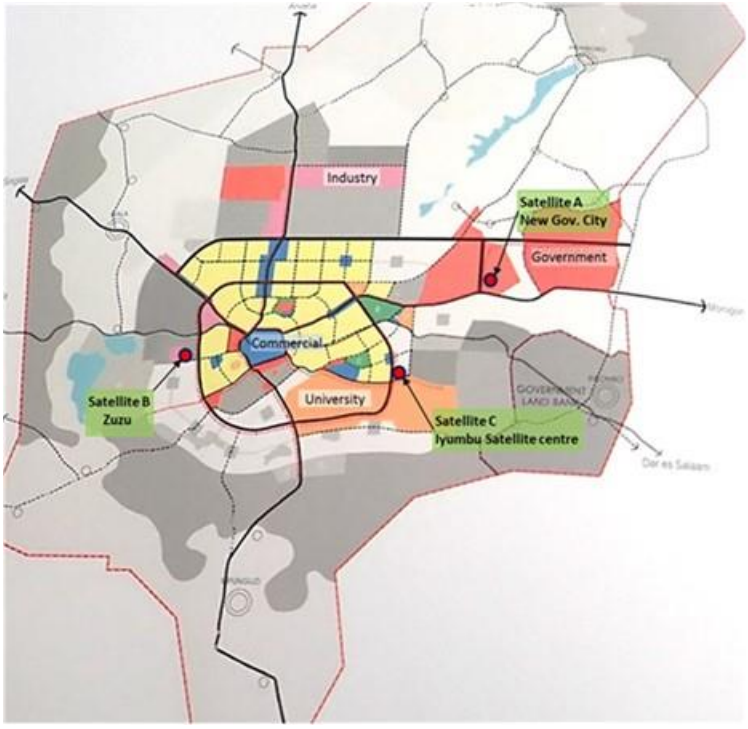
considered, as there are few residential dwellings around the area that have just started development.

- Satellite B, there seems enough space for installation in TANESCO site, as TANESCO has a relatively large area including substations adjoining the Zuzu power station.
- As shown in Figure 12.4-13, Satellite C is in or near the residential area that is currently under development, and a vast amount of vacant space is spreading around the area. The exact location is to be determined in coordination with future development plans. Considering the current surrounding conditions, there seems to be a sufficient space for possible locations.

The three satellite facilities are close to the planned routes of the major roads, and therefore, the transportation vehicles access is not considered to be a major problem.



Source: prepared by a JICA study team based on Dodoma Capital City Master Plan 2030

Figure 12.5-2 Land use plan and candidate areas for satellite facilities in Dodoma

</td>
</tr>
<tr>
<td>Cultural Heritage</td>
<td>Cultural heritage sites both in Dar es Salaam and Dodoma are unlikely to be affected because they are far from the areas where mini-LNG plants and satellite facilities are to be installed.</td>
</tr>
<tr>
<td>Accidents</td>
<td>Schools and dispensary are located near the potential transportation route from Kinyerezi Energy Complex to the main road, construction vehicle and gas transportation vehicle traffic may have some impact on safe access to such social institutions and decision making institutions of local centres.</td>
</tr>
</table>

12.6 Assessment of the impact of alternative scenarios

In Tanzania, residential sector, the largest energy consumption sector, heavily relies on traditional biofuels such as firewood and charcoal. Introduction of natural gas supply system will significantly contribute to reduction of further increase of biofuel consumption, improvement of domestic air quality that would cause lung disease, prevention of deforestation, control of GHG emissions and control of foreign currency outflow caused by increasing import of LPG and petroleum products. In consideration of such analysis developed in the previous chapters, based on the concept of the SEA based on the scoping, this project compared and examined the means of transportation related to the domestic supply of natural gas (Table 12.6-1).

The gas pipeline scenario has a large social impact because the land acquisition area is as large as 1,500 ha, and the impact of land modification on the ecosystem is greater than the other two scenarios. On the other hand, in the scenario of transportation by CNG and LNG, since it is transported through existing roads or railroads, the need for land acquisition is limited and the impact on the natural environment is small. Comparing the CNG and LNG scenarios, the LNG transportation scenario requires less land area and has less impact. On the economic side, the pipeline scenario has the largest investment required among these, and the LNG scenario has the smallest. Based on these, the LNG transportation scenario is considered to be the most desirable scenario from the viewpoints of natural environment, social environment, and economic aspect.

As analysed in this report, the virtual pipeline system based on mini-LNG is most suitable for delivery of small amount of natural gas to the local markets. However, in case any big power plant to use natural gas in a large quantity is to be built, it is expected that pipeline will be by far favourable in terms of both environment and economics. Therefore, the national natural gas supply system should be designed in close collaboration with electricity supply plan. This Study had materially completed by the summer of 2019. After that, the PSMP 2020 Update was announced in September 2020 which schedules construction of large scale gas fired power stations in Dodoma and Bagamoyo beyond the reach of the existing pipeline. In view of this development, we should note that the project structure examined in this study needs to be reviewed appropriately.

Table 12.6-1 Assessment of the impact of alternative scenarios

Outline of each scenario					
	LNG scenario		**CNG scenario**		**Pipeline scenario**
Overview of the system	Liquefied at mini-LNG plant in Kinyerezi Energy Complex and transported by tank-truck, or trailers or trains with container to the LNG satellite.		Compressed (pressurized) at CNG plant in Kinyerezi Energy Complex and transported by tank-truck, or trailers or trains with container to the CNG satellite.		Gas is received from the gas terminal at Kinyerezi Energy Complex with the receiving pressure at 70 bars and is transported by gas pipeline to the receiving gas terminal with the arrival pressure at the destination at 60 bars.
Major component	**Mini-LNG plant** 1) Gas engine generator 2) Cryogenic heat exchanger made of aluminum 3) Refrigerant compressor and its driver 4) Air separator (to produce N_2 as refrigerant) 5) Storage: Bullet type LNG tank (600kL) x 2 6) LNG loading/shipping facility Transportation: Capacity of a container:18 tons for LNG	**LNG Satellite** 1) Truck yard 2) Bay for unloading 3) LNG tank 4) Vaporizer 5) Control system	**CNG Plant** 1) Piping to receive the feedgas 2) Pre-treatment system for dehydration 3) Gas compressors 4) Gas cooling system 5) Gas loading/shipping bays Transportation: Capacity of a container: 7.5 tons for CNG of 250 kg/cm^2.	**CNG Satellite** 1) Truck yard 2) Bay for unloading 3) Gas tank 4) Control system	1)12" or 20" pipeline (steel pipeline with design pressure capacity of 75 bars, 500km 2) Pig stations for maintenance and cleaning 3) Safety systems with emergency block valves and relief valves 4) Metering stations for identification of transaction amount 5) Pressure control systems 6) Control center to monitor, control and record the gas flow and pressure, etc.
Capital investment cost	116-217 million USD		89-271 million USD		525-556 million USD
Gas transportation cost (Ex-satellite)	18.30 USD/MMBtu (66,000 t-LNGeq/year) 14.04 USD/MMBtu (132,000 t-LNGeq/year)		15.55 USD/MMBtu (66,000 t-LNGeq/year) 14.42 USD/MMBtu (132,000 t-LNGeq/year)		44.89 USD/MMBtu (90,000 t-LNGeq/year) 20.93 USD/MMBtu (323,000 t-LNGeq/year)

Outline of each scenario					
	LNG scenario		**CNG scenario**		**Pipeline scenario**
Capacity	**Mini-LNG Plant**	**LNG Satellite**	**CNG Plant**	**CNG Satellite**	**Pipeline**
	100 t/day to 200t/day x 2 trains (66,000 -132,000 t-LNGeq/year)	5-50 t/day, Max 170t/day	100 t/day to 200t/day x 2 trains (66,000 -132,000 t-LNGeq/year)	2.5-5 ton/day	12" pipeline: 14,000m^3/hour (90,000 t-LNGeq/year) 20" pipeline: 50,000m^3/hour (323,000 t-LNGeq/year)

Natural Environment					
	LNG scenario		**CNG scenario**		**Pipeline scenario**
	Mini-LNG Plant	LNG Satellite	CNG Plant	CNG Satellite	Pipeline
Protected area	Facilities are not to be located in protected areas	Facilities are not to be located in protected areas	Facilities are not to be located in protected areas	Facilities are not to be located in protected areas	Gas pipeline might be passing through protected areas between Dar es Salaam and Dodoma
Ecosystem	**Mini-LNG plant** is expected to be located in Kinyerezi Energy Complex, industrial area. No impact on ecosystem is expected.	**LNG satellites** are expected to be located in urban area. No impact on ecosystem is expected.	**CNG plant** is expected to be located in Kinyerezi Energy Complex, industrial area. No impact on ecosystem is expected.	**CNG satellites** are expected to be located in urban area. No impact on ecosystem is expected.	Pipeline would pass through forest reserves and wildlife corridors. 1,500 ha of vegetation removal along the route, habitat alteration and obstruction to wildlife movements might also be expected.
	Transportation: Potential transportation route passes through several wildlife corridors and protected areas. Potential risk is wildlife strike in such areas especially at night.		**Transportation:** Potential transportation route passes through several wildlife corridors and protected areas. Potential risk is wildlife strike in such areas especially at night.		
Soil	Relatively small area is required and soil erosion is expected to be small.	Relatively small area is required and soil erosion is expected to be small.	Relatively small area is required and soil erosion is expected to be small.	Relatively small area is required and soil erosion is expected to be small.	1,500 ha of vegetation removal due to the pipeline installation would cause soil erosion along the route of 500km

Natural Environment					
	LNG scenario		**CNG scenario**		**Pipeline scenario**
	Mini-LNG Plant	LNG Satellite	CNG Plant	CNG Satellite	Pipeline
Water use	1) For regular operation, industrial water supply is nor necessary. 2) For maintenance and repair work, water requirement is 50-100m^3/hour (short time), Total amount 50-100m^3	Negligible (Little water is required at satellites.)	Negligible (Little water is required at plant.)	Negligible (Little water is required at satellites.)	
Wastewater	**Construction phase**: Strom water from the site may affect surface water in discharged areas. Operation Phase: **0.2-0.4 ton/hour** (4.8-9.6 ton/day) <Waste water source> - Dehydration process - Maintenance wastewater from the plant - Storm water from the site (Retention basin and Oil-water separator to be installed. No pH adjustment necessary.)	Construction Phase: Strom water from the site may affect surface water in discharged areas. Impact will be limited as the site is narrow. Operation Phase: Negligible (Only storm water from the site. Oil-water separator to be installed at the site for storm water. No process wastewater is expected.)	Construction Phase: Strom water from the site may affect surface water in discharged areas. Operation Phase Negligible (Only storm water from the site. Oil -water separator to be installed at the site for storm water. No process wastewater is expected.)	Construction Phase: Strom water from the site may affect surface water in discharged areas. Impact will be limited as the site is narrow. Operation Phase: Operation Phase: Negligible (Only storm water from the site. Oil -water separators to be installed at the site for storm water. No process wastewater is expected.)	Operation Phase: Negligible (There are no significant point source emissions or effluents.)
Air emission	**Construction Phase:** Air quality deterioration may occur temporarily at the site due to dust caused by operation of construction machines.	**Construction Phase:** Air quality deterioration may occur temporarily at the site due to dust caused by operation of construction machines.	**Construction Phase:** Air quality deterioration may occur temporarily at the site due to dust caused by operation of construction machines.	**Construction Phase:** Air quality deterioration may occur temporarily at the site due to dust caused by operation of construction machines.	**Construction Phase:** Air quality deterioration may occur temporarily at the site due to dust caused by operation of construction machines.

Natural Environment					
	LNG scenario		**CNG scenario**		**Pipeline scenario**
	Mini-LNG Plant	LNG Satellite	CNG Plant	CNG Satellite	Pipeline
	Operation Phase: CO_2 : 1.2-2.4 ton/hr (**10,512-21,024ton/year**) <GHG emission source> - Emission from Acid removal process - Combustion by Gas engine generator <10MW	**Operation Phase:** Negligible (No combustion is expected)	**Operation Phase:** Negligible (No combustion is expected)	**Operation Phase:** Negligible (No combustion is expected)	
	NOx: 50-150ppm <NOx emission source> - Combustion by Gas engine generator <10MW	Some CH_4 from LNG tank			
	GHG emission from transportation vehicle (Diesel truck): 2025: **1,603-3,790 ton-CO_2 eq/year** 2030: **3,058-7,288 ton-CO_2 eq/year** If CNG is used for vehicle fuel, GHG emission is approx. 20% less.		GHG emission from transportation vehicle (Diesel truck): 2025: **3,790-8,745 ton-CO_2 eq/year** 2030: **7,434-17,342 ton-CO_2 eq/year** If CNG is used for vehicle fuel, GHG emission is approx. 20% less.		GHG emission from natural gas transmission pipeline: 12" pipeline: **570-3,777 ton-CO_2 eq/year** 20" pipeline: **2,036-13,491ton-CO_2 eq/year**
Noise level of the major sources (1m from the source)	**Construction Phase:** Noise and vibration may occur in the adjacent areas due to operation of heavy machines and material transport. **Operation Phase:** **85dBA** <Major noise source> - Air coolers - Compressor, Expander	**Construction Phase:** Noise and vibration may occur in the adjacent areas due to operation of heavy machines and material transport. (For relatively short period) **Operation Phase:** **85dBA** <Major noise source> - Compressor - Pump	**Construction Phase:** Noise and vibration may occur in the adjacent areas due to operation of heavy machines and material transport. (For relatively short period) **Operation Phase:** **85dBA** <Major noise source> - Compressor	**Construction Phase:** Noise and vibration may occur in the adjacent areas due to operation of heavy machines and material transport. (For relatively short period) **Operation Phase:** **85dBA** <Major noise source> - Compressor	**Construction Phase:** Noise and vibration may occur in the adjacent areas due to operation of heavy machines and material transport.

Natural Environment					
	LNG scenario		**CNG scenario**		**Pipeline scenario**
	Mini-LNG Plant	LNG Satellite	CNG Plant	CNG Satellite	Pipeline
Waste	1) General waste - General office and packaging wastes 2) Some hazardous waste -Oily sludge from oil-water separators -Mercury adsorbents (disposed every four years) -H2S adsorbents (amine) from acid removal unit	1) General waste -General office and packaging wastes 2) Some hazardous waste -Maintenance	1) General waste -General office and packaging wastes 2) Some hazardous waste -Maintenance	1) General waste -General office and packaging wastes 2) Some hazardous waste -Maintenance	
Material	Concrete: 3,000-6,000 m^3 Rebar: 200-400 ton Steel: 300-600 ton	Small satellite: Concrete: 300 m^3/satellite Steel: 40 ton/satellite	Concrete: 800-1,600 m^3 Steel: 80-160 ton	Small satellite: Concrete: 150 m^3/satellite Steel: 20 ton/satellite	Concrete: 50,000m^3 Rebar: 1,500 ton Sand: 1,750,000m^3, Backfill: 875,000m^3 Soil disposal: 1,750,000m^3

Social environment			
	LNG scenario	**CNG scenario**	**Pipeline scenario**
Land acquisition, resettlement	Required land: **Approx. 3.25ha** Mini-LNG plant = 180m x 150m (2.7ha), Satellites = 0.55 ha Storage tanks in Satellite (not so much space is necessary) A: 1000kl x 2 (20m x 20m: 0.04ha) B: 3000kl x 2 (70m x 70m: 0.49ha) C: 100kl x 2 (20 m x 10m: 0.02ha) For industrial use, LNG receiving satellites are expected to be located within the customers compound (e.g. factory compounds) as customers' facilities, thus little additional land acquisition is expected for industrial use in Arusha, Tanga, and Morogoro.	Required land: **Approx. 5.5ha** CNG Plant = 50m x 50m (0.25ha), Satellites: Approx. 5ha Storage containers in Satellite (rather large space is expected to be necessary) 92-441 containers (Capacity: 7.5 ton/container) Small satellite: 20m x 20m(0.04ha), Large Satellite: 200m x 200m (4ha) For industrial use, CNG receiving satellites are expected to be located within the customers compound (e.g. factory compounds) as customers' facilities, thus little additional land acquisition is expected for industrial use in Arusha, Tanga, and Morogoro.	Required land: **Approx. 1,500ha**
	Less land acquisition impact. Required land is smaller than CNG system.	More land would be necessary than LNG system.	Resettlement impact is expected to be large.
Traffic	11-26 vehicles required in 2025 ->132 trips/month (**4.4trips/day**)-312trips/month (**10.4trips/day**) 21-50 vehicles requires in 2030 -> 252 trips/month (**8.4trips/day**)-600 trips/months (**20 trips/day**)	26-60 vehicles required in 2025 -> 312trips/month (**10.4trips/day**)-720trips/month(**24trips/day**) 51-119 vehicles required in 2030 -> 612trips/month(**20.4trips/day**)-1,428trips/month(**47.6trips/day**)	None
	12 round trips a month/vehicles (24 days per month/vehicle) Diesel: 368ltr/trip -> Annual diesel consumption 2025: 1,584 trips/year (**583kL/year**)-3,744trips/year(**1,378kL/year**) 2030: 3,024trips/year (**1,112kL/year**)-7,200trips/year(**2,650kL/year**)	12 round trips a month/vehicle (24 days per month/vehicle) Diesel: 368ltr/trip -> Annual diesel consumption 2025: 3,744trips/year (**1,378kL/year**)-8,640trips/year (**3,180kL/year**) 2030: 7,344 trips/year (**2,703kL/year**)-17,136trips/year (**6,306kL/year**)	
	<Construction>	**<Construction>**	**<Construction>**

<table>
<tr><th colspan="6">Social environment</th></tr>
<tr><th></th><th colspan="2">LNG scenario</th><th colspan="2">CNG scenario</th><th>Pipeline scenario</th></tr>
<tr><td rowspan="4">Workforce/ labor size</td><td>Mini-LNG plant:
Approx. 200-400 workers</td><td>LNG Satellites:
Approx. 30-60 workers</td><td>CNG plant:
Approx. 60-120 workers</td><td>CNG Satellites:
Approx. 30 workers</td><td>Gas pipeline:
Approx. 80 workers</td></tr>
<tr><td colspan="2"><Operation></td><td colspan="2"><Operation></td><td><Operation></td></tr>
<tr><td>Approx. 19 staff
Operated 24 hours with three shifts a day</td><td>Approx. 26 staff</td><td>Approx. 5 staff
Operated with one shift a day</td><td>Approx. 34 staff</td><td rowspan="2">Approx. 15 staff</td></tr>
<tr><td colspan="2">For Transportation
2025: 17-46 drivers
2030: 27-88 drivers</td><td colspan="2">For Transportation
2025: 40-111 drivers
2030: 65-208 drivers</td></tr>
<tr><td>Health, Safety and Security risk</td><td colspan="2">1) LNG leakage from LNG tank
2) LNG spillage in transporting, loading
3) Potential for releases of hydrogen sulfide (H_2S) from liquefaction unit.
4) Storage and handling of LNG may expose personnel to contact with very low-temperature product.
5) Fires and explosions
6) Traffic safety in relation to transportation vehicles</td><td colspan="2">1) CNG leakage from equipment such as pipe, gas compressing unit, dispenser, CNG tube tank.
2) Fires and explosions: CNG has a higher flashpoint and auto-ignition temperature than diesel fuel.
3) Traffic safety in relation to transportation vehicles</td><td>1) Leak and corrosion of gas pipeline
2) Exposure to gas leaks and explosions
3) Potential interference with other underground infrastructure, road construction, excavation, etc.
4) Erosion of pipeline cover, pipeline floatation by flooding event
5) Induced voltages and fault currents, such as by nearby railway, high voltage power transmission line</td></tr>
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12.7 Mitigation measures for priority scenarios

Table 12.7-1 shows the potential mitigation measures for the major potential impacts in construction phase of the Priority Scenario, transporting natural gas from Dar es Salaam to Dodoma in the Form of LNG. When implementing this plan, detail mitigation measures are to be studied in project EIA considering the specific project plans.

1) Construction phase

Table 12.7-1 Mitigation Measures for the Major Impacts of Construction Phase in the Preferred Scenario (Transporting Natural Gas from Dar es Salaam to Dodoma in the Form of LNG)

Category	Project Activity and Affected Area	Potential Impacts	Potential Mitigation Measures
Air pollution	• Site preparation, filling and levelling. • Excavation of soil for building and equipment foundations. • Pile driving for the equipment foundation. • Concrete works. • Transportation related activities	• Dust Generation	• Water spraying of or covering exposed areas and stockpiles, if necessary. • Specifying transport networks and locating stockpiles as far away from the site boundary which is close to the air sensitive receptors, as practicable to minimize the impact of air pollutants and dust. • Minimizing the size of exposed areas and material stockpiles and the periods of their existence. • Temporary stockpiles of dusty materials will be either covered by impervious sheets or sprayed with water. • Prohibiting the burning of waste or vegetation on site.
	• Operation of heavy machinery and transport vehicles	• Vehicle exhaust	• Maintaining and checking the construction equipment regularly.
Water pollution	• Wastewater Discharges and Runoff • Excavation of soil for building and equipment foundations	• Impaired quality of water resources (surface/subsurface water, groundwater) • Reduced surface water infiltration	• Adequate sanitary facilities will be provided for the construction workforce. Septic tanks will be provided to treat sanitary discharge. • Liquid effluents arising from construction activities will be treated to applicable standards (i.e. Tanzanian standards, IFC Performance Standards, IFC EHS Guidelines) prior to discharge. • Design drainage for the controlled release of storm flows within site boundary for the project. • Regularly, and particularly following rainstorms, inspect and maintain drainage and erosion control and silt removal measures to ensure proper and efficient management at all times. • Provide measures to prevent the washing away of construction materials, soil, silt or debris into any drainage of open stockpiles of construction materials. • Wastewater collected from canteen kitchens, including that from basins, sinks and floor drains, should be discharged

Category	Project Activity and Affected Area	Potential Impacts	Potential Mitigation Measures
			into sanitary sewers via grease traps. • Oil-contaminated water will be collected and handled by local licensed wastewater sub-contractors.
	• Waste Storage and Disposal	• Impaired quality of water resources (surface/subsurface water, groundwater)	• Provide training to labourers for waste disposal in designated areas and use of sanitation facilities. • Implement proper storage of the construction materials and wastes to minimise the potential damage or contamination of the materials. • Segregate hazardous and non-hazardous waste and provide appropriate containers for the type of waste type. • Ensure that storage areas have impermeable floors and containment. • Dispose of waste by licensed contractors.
	• Accidental Spills and Leaks	• Impaired quality of water resources (surface/subsurface water, groundwater)	• Disposal sites to be designed for hazardous and non-hazardous waste, including sludge disposal. • Hazardous waste storage areas will comply with best practice/ international standards. • Mitigation measures/ monitoring programme with regard to accidental events/ spills shall be communicated to the contractor at the early stages of the project implementation. • Contractor will prepare unloading and loading protocols and train staff to prevent spills and leaks. • Contractor will prepare guidelines and procedures for immediate clean-up actions following any spillages of oils, fuels or chemicals. • The storage areas for oil, fuel and chemicals will be surrounded by bunds or other containment devices to prevent spilled oil, fuel and chemicals from percolating into the ground or reaching the receiving waters. • Provide dedicated storage areas for construction materials to minimise the potential for damage or contamination of the materials.
Soil	• Site clearing, sand filling and site preparation	• Loss of Soil due to improper management during site clearance activities	• Scheduling clearance activities, if possible to avoid extreme weather events such as heavy rainfall, extreme dry and high winds. • Revegetation areas with temporary land use, conducting progressive rehabilitation. • Demarcate routes for movement of heavy vehicles to minimise disturbance of exposed soils and compaction of sub-surface layers. • Control erosion through diversion drains, sediment fences, and sediment retention basins.
	• Storage, handling and disposal of construction waste	• Soil contamination due to potential leaks, spills and importation of contaminated fill material during construction	• Unloading and loading protocols will be developed to ensure that staff are able to undertake these tasks in a manner that minimises the risks of spills occurring. • Fuel tanks and chemical storage areas will be sited on sealed hardstand areas. • Secondary containment, with appropriate drainage connection and/or provision for removal of spilled liquids, will be provided around places of fuel and hazardous materials storage to contain any hazardous spills and to exclude surface water run-off from entering the contained area. • Any refuelling activities will only take place within a designated hard stand area. • A dedicated storage area for construction material will be developed to minimise the potential for damage or contamination of the material. • No sanitary effluent is to be disposed of on, or adjoining the site. • A training program will be implemented to familiarise staff with measures to be taken to prevent spills and leaks,

Category	Project Activity and Affected Area	Potential Impacts	Potential Mitigation Measures
			and for emergency procedures and practices related to contamination events.
Waste	• General Construction works	• Generate solid and hazardous wastes • Spillage of oil and any hazardous material	• Prior to commencement of construction, a waste management plan is to be developed which includes specific requirements to manage, avoid, reduce and reuse during the construction and operation phases for all the waste streams identified. • Prior to commencement of construction, the contractor will be engaged with local authorities and other stakeholders to determine the capacity of the local waste management network to absorb the waste streams during construction. • Waste disposal facilities shall be sited and signposted in the project site. • All waste collected should be managed, segregated, and disposed of in accordance with the applicable regulations. • Training to workers on site shall be undertaken to avoid, reduce and reuse wastes generated.
Noise and vibration	• Heavy machinery operations for construction works. • Piling for equipment foundation Transportation related activities	• Increased noise and/or vibration disturbance	• Well-maintained equipment to be operated on-site. • Reduce the number of equipment operating simultaneously as far as practicable. • Locate noisy and/or vibrant machines (such as hydraulic hammer and lorry mounted concrete pump) as far away from receptors as practicable. • Prepare the plan for transportation of materials on- and off-site through the access road adjacent to the residential area. • Use material stockpiles and other structures, where practicable, to screen noise sensitive receptors from on-site construction activities. • Transport construction materials only during day time. • Contractors should avoid passing through resident areas as much as possible.
Odour	Wastes during construction	• Odour from wastes not properly managed at site	• Conduct proper management of wastes.
Bottom Sediment	Erosion of soil during construction	• Spill over of eroded soil during construction	• Properly plan and manage use of heavy machines at the construction site.
Topology and Geographical Features	Land reclamation during construction	• Topology change by land reclamation	• Minimize topology change by minimal land excavation and transfer of soil.
Land acquisition and Resettlement	Land acquisition, if necessary, for satellites, access road, or any associated facilities	• Physical and economical displacement of people in the proposed project site	• If land acquisition is necessary to implement the project, TPDC needs compensate for the loss to the affected people to mitigate the impacts by the land acquisition and resettlement. The compensation policy is developed in line with the national law and the lenders' requirement (i.e. JICA guidelines, World Bank safeguard policy, IFC performance Standards), and Resettlement Action Plan (RAP) or Abbreviated Resettlement Action Plan (ARAP) is to be developed. • Provide assistance to vulnerable people, if identified in the project affected people (PAPs). • Check if there are indigenous peoples and ethnic minorities in the land acquisition target area, and if so, create an Indigenous People Plan.

Category	Project Activity and Affected Area	Potential Impacts	Potential Mitigation Measures
		• Complains regarding land acquisition and resettlement such as compensation, land use conflicts and water use conflicts	• Grievance redress mechanisms are ensured as tools for allowing affected people to voice concerns about the resettlement and compensation process as they arise and, if necessary, for corrective action to be taken expeditiously.
Community infrastructure and public services	• Increased construction worker • Transportation of personnel and use of road network	• Increased pressure on social services	• Provide appropriate amenities at the project site. This will help reduce the need for workers to utilize local infrastructure and services. • Develop and implement a site safety management plan. This plan will need to ensure appropriate and adequate health care services are provided on site to address/ manage worker illnesses and injuries.
Indigenous peoples and ethnic minorities	Increased construction worker	• Increased pressure on social services and resources indigenous peoples and ethnic minorities use	• Check if there are indigenous peoples and ethnic minorities in the project area, and if so, create an Indigenous People Plan.
Employment and economy	General Construction activities	• Increased local market opportunities • Increased local employment	• Inform local people of job opportunities in a timely and fairly manner. • Inform local businesses of contracting opportunities in a timely manner such as awareness on forthcoming investment and employment opportunities, including sensitization of farmers for production of required quality of foods such as vegetables.
Landscape	General Construction activities	• Temporary landscape changes due to installation and operation of construction machinery	• Consider the local landscape when operating construction machinery.
Cultural heritage	General Construction activities	• Loss of heritage artifacts if discovered in the project site	• Ensure procedure implemented if heritage artifacts discovered in the project site. In case of such discovery during the construction activities, it is to be reported to the relevant authorities such as District Councils and the Antiquities division of the Ministry of Natural Resource and Tourism (MNRT). • Ensure no cultural site, when notified prior to works, is disturbed without community agreement.
Community Health and safety	Influx of construction workers	• Increased risk of HIV/AIDS and other STDs	• Training for all workers on communicable diseases as well as sensitization of enforcement of HIV/AIDS law and regulations. This can help reduce the potential for workers to unknowingly transmit communicable diseases. • Establish a workforce code of conduct. Include in the code specific measures on anti-social behaviour. • Vector management procedures, including consideration of whether pesticides will be utilized to reduce the presence of vectors onsite. • Emergency management procedures, should a health issue escalate and require a rapid response.
Community safety and	• Influx of construction workers	• Increased crime and insecurity	• Explore opportunities to work with local stakeholders to increase awareness within local villages about the hazards associated with traffic. Consider women who use local medical institutions and children who go to school.

Category	Project Activity and Affected Area	Potential Impacts	Potential Mitigation Measures
security, Occupational Health and Safety	• Heavy traffic movement	• Increase risks, hazards and accidents	• Equip the first aid kit in the project site. • Provide appropriate training for security personnel and monitor implementation of the training over time and create awareness on all security issues in the area. • Construct fence, install security lights that will benefit the surrounding areas, and storage facilities.

2) Operation phase

Table 12.7-2 Mitigation Measures for the Major Effects of Operational Stages in Preferred Scenarios (Transporting and Supplying Natural Gas from Dars Salaam to Dodoma in the form of LNG)

Category	Project Activity and Affected Area	Potential Impacts	Potential Mitigation Measures
Air pollution	NOx emissions	• Impact on ambient air quality	• Monitor the NOx emission concentrations and other relevant parameters at emission point to ensure that NOx emissions are within the emission limit as recommended in the IFC Emission Guideline.
	CO_2 emissions (LNG plant operation, LNG transportation)	• GHG generation	• Conduct annual pollutant release inventory to monitor the GHG emissions from the project. The GHGs emission shall be reported as CO2e unit. GHGs emission is monitored through calculation by the amount of natural gas that is actually used for operation of the plant. • Methane and carbon dioxide emissions are powerful greenhouse gases. In an LNG facility, small gas flares are needed for operational safety but flaring should be minimized. Methane emissions must be measured and mitigated including processing equipment, storage tanks, valves, compressors, and other fugitive sources.
	After LNG liquefaction, stored LNG emits a small amount of methane gas vapor known as boil-off gas (BOG)	• Methane gas vapour emission	• For LNG plant, the vapor should be returned to the process for liquefaction or used on-site as a fuel. • For re-gasification facilities (LNG satellite terminals), the collected vapors should be returned to the process system to be used as a fuel on-site, compressed and placed into the sales stream, or flared.
Water pollution	Wastewater Discharges and Runoff	• Impaired quality of water resources (surface/subsurface water, groundwater)	• Install oil/water separators to treat surface run-off prior to discharge to the storm water system. Separated oil will be disposed of as part of oily wastes and handled as a hazardous waste stream. • Implement adequate sanitary facilities for onsite personnel. • Design drainage culverts for the controlled release of storm flows. • Storm water drainage, sewage and wastewater at mini-LNG plant will be treated prior to discharge to the discharge point and the treated effluent will comply with WB/IFC EHS Guidelines.
	Waste Storage and Disposal	• Impaired quality of water resources (surface/subsurface water, groundwater)	• Provide training to all staff for waste disposal in designated areas and use of sanitation facilities. • Segregate hazardous and non-hazardous waste and provide appropriate containers for the type of waste type. • Ensure that storage areas have impermeable floors and containment. • Dispose of waste by licensed contractors.

Category	Project Activity and Affected Area	Potential Impacts	Potential Mitigation Measures
	Accidental Spills and Leaks	• Impaired quality of water resources (surface/subsurface water, groundwater)	• The storage areas for oil, fuel, chemicals and waste will be surrounded by containment/spill control measure to prevent spilled oil, fuel and chemicals from percolating into the ground or reaching the receiving waters. • All drainage/tanks, etc. will be positioned on concrete hard standing to prevent any seepage into ground. • Guidelines and procedures should be established for immediate clean up actions following any spillages of oil, fuel or chemicals.
	Storage, transfer, and transport of LNG may result in leaks or accidental release, it also poses a risk of fire and explosion.	• Risk of fire and explosion	• LNG storage tanks and components (e.g. pipes, valves, and pumps) should meet international standards for structural design integrity and operational performance to avoid catastrophic failures and to prevent fires and explosions during normal operations and during exposure to natural hazards. • Storage tanks and components (e.g. roofs and seals) should undergo periodic inspection for corrosion and structural integrity and be subject to regular maintenance and replacement of equipment (e.g. pipes, seals, connectors, and valves). A cathodic protection system should be installed to prevent or minimize corrosion, as necessary. • Loading / unloading activities of LNG should be conducted by properly trained personnel according to pre-established formal procedures to prevent accidental releases and fire / explosion hazards. Procedures should include all aspects of the delivery or loading operation from arrival to departure, such as secure connection of grounding systems, verification of proper hose connection and disconnection, adherence to no smoking and no naked light policies for personnel and visitors.
Soil	Reduced surface water infiltration	• Loss of soil	• Ensure that drainage channel is designed with enough capacity to accommodate the increased rainfall runoff from the project's impervious surfaces.
	Storage, handling and disposal of waste in operation	• Soil contamination due to potential leaks and spills	• All drainage/tanks will be positioned on concrete hard standing to prevent any seepage into ground. • Standard Operation Procedures (SOPs) will be prepared to manage any oil spills, leaks and/or seepages. SOPs will cover transport, handling, storage, use and disposal of oil/ oil wastes/ empty drums. Operating personnel will be trained on the SOPs.
Waste	Plant operations	• Waste Generation (General office and packaging wastes, waste oils, used batteries, empty paint cans, spent dehydration media (e.g., molecular sieves) and oily sludge from oil-water separators, spent amine from acid gas removal units, among others.)	• A waste management plan will be developed. It will include specific requirements to manage, avoid, reduce and reuse during operation phase for all the waste streams identified. • Training about waste management – avoid, reduce and reuse wastes will be provided to employees. • Waste segregation will be properly implemented. • Waste disposal facilities shall be sited and signposted in the project site. • All waste collected should be managed and disposed of in accordance with the required regulations. • Monitoring of appointed waste contractors to ensure proper waste disposal, in accordance with applicable regulations.
Noise and vibration	Plant operations (Main noise emission sources in LNG facilities include pumps,	• Increased noise and/or vibration disturbance	• Selecting quieter equipment. • Installing silencers, mufflers or acoustic enclosures to reduce sound power level of noisy equipment at all times if necessary.

Category	Project Activity and Affected Area	Potential Impacts	Potential Mitigation Measures
	compressors, generators and drivers, air coolers)		• Locating noise and/or vibration sources to less sensitive areas to take advantage of distance and shielding. • Conduct regular noise level measurements to monitor noise generated by the project. • Plant trees as a green belt along the site boundary near the NSRs to minimise noise impacts.
Terrestrial ecology	LNG transportation by vehicle	• Impact on vulnerable species, local terrestrial biodiversity and wild life	• Vehicles and machinery will be maintained in accordance with industry standard to minimise unnecessary noise generation. • Appropriate speed limits and operation plan for vehicles when transporting LNG via main road from Dar es Salaam to Morogoro, Dodoma, and Tanga will be enforced to minimise potential for fauna strike especially nearby wildlife corridor and forest reserves.
Community infrastructure and public services	Operation of the project	• Increased pressure on social services	• Develop and implement a site safety management plan. This plan will need to ensure appropriate and adequate health care services are provided on site and at the worker camp to address/ manage worker illnesses and injuries.
Indigenous peoples and ethnic minorities.	Operation of the project	• Increased pressure on social services and resources indigenous peoples and ethnic minorities use	• Check if there are indigenous peoples and ethnic minorities in the project area, and if so, create an Indigenous People Plan.
Employment and economy	Operation of the project and development of the neighbouring communities	• Increased local market opportunities • Increased local employment	• Inform local villagers of job opportunities in a timely manner. • Inform local businesses of contracting opportunities in a timely manner such as awareness on forthcoming investment and employment opportunities, including sensitization of farmers for production of required quality of foods such as vegetables.
Community health	Operation of the project and increased populations in the neighbouring communities	• Increased risk of HIV/AIDS and other STDs	• Training for all workers on communicable diseases as well as sensitization of enforcement of HIV/AIDS law and regulations. This can help reduce the potential for workers to unknowingly transmit communicable diseases. • Establish a workforce code of conduct. Include in the code specific measures on anti-social behaviour. • Vector management procedures, including consideration of whether pesticides will be utilized to reduce the presence of vectors onsite. • Emergency management procedures, should a health issue escalate and require a rapid response.
Community safety and security, Occupational Health and Safety	Operation of the project	• Increase risks, hazards and accidents	• Explore opportunities to work with local stakeholders to increase awareness within local community about the hazards associated with traffic. Consider women who use local medical institutions and children who go to school. • Equip the first aid kit in the project site. • Provide appropriate training for security personnel and monitor implementation of the training over time and create awareness on all security issues including activities in the area.
	LNG Transport	• BOG build-up during transport, and leakages from the tank	• LNG road tankers or containers should be constructed as double-walled, with a combined vacuum and insulation system to keep the cryogenic liquid cool during transportation.
	Loading and unloading of LNG	Fires and Explosions	• Implement safety procedures for loading and unloading of the product to rail and tanker trucks, including use of fail-

Category	Project Activity and Affected Area	Potential Impacts	Potential Mitigation Measures
	An uncontrolled release of LNG could lead to jet or pool fires if an ignition source is present, or a methane vapor cloud under unconfined conditions which is potentially flammable (flash fire). LNG spilled directly onto a warm surface (such as water) could result in a sudden phase change and inflation known as a Rapid Phase Transition (RPT), which can also cause damage to nearby structures. Storage and handling of LNG	• Risk of fire (Jet or pool fires, Rapid Phase Transition)	safe control valves and ESD equipment. • Prevent potential ignition sources by ensuring proper grounding to avoid static electricity buildup and lightning hazards (including procedures for the use and maintenance of grounding connections). • Properly equip facilities with fire detection and suppression equipment that meets internationally recognized technical specifications for the type and amount of flammable and combustible materials stored at the facility. • Fixed fire suppression systems may also include foam extinguishers attached to tanks, and automatic or manually operated fire protection systems at loading/unloading areas. **Water is not suitable for fighting LNG fires**, as it increases the vaporization rate of LNG. • While LNG is inherently a safe substance which does not burn directly, the vapor that it generates, effectively natural gas, is flammable, and care must be taken in handling vapor to avoid a release. In many countries, LNG is classified as a hazardous material (despite the industry's excellent safety record and the stability of LNG until it starts vaporizing), and rigorous standards often apply to its storage and transportation. Various international or trade bodies also publish safety standards, some of which are used internationally. • Conduct a **spill risk assessment** for the facilities and related transport activities. • Develop a formal **spill prevention and control plan** that addresses significant scenarios and magnitude of releases. Spill response equipment should be conveniently available to address all types of spills. • Facilities should be equipped with a system for the early detection of gas releases, designed to identify the existence of a gas release and to help pinpoint its source. • An **Emergency Shutdown and Detection system** should be available to initiate automatic transfer shutdown actions in case of a significant LNG leak. • Facilities should provide grading, drainage, or impoundment for vaporization process, or transfer areas able to contain LNG. • In the case of a gas release, safe dispersion of the released gas should be allowed, maximizing ventilation of areas and minimizing the possibility that gas can accumulate in closed or partially closed spaces. Spilled LNG should be left to evaporate. • For unloading/loading activities involving LNG carriers and terminals, prepare and implement spill prevention procedures for carrier loading and off-loading.
		Contact with Cold Surfaces	• Plant equipment that can pose an occupational risk due to low temperatures should be adequately identified and protected (e.g., insulated) to reduce accidental contact with personnel. Training should be provided to educate workers handling or dispensing LNG (e.g., at LNG fuel stations) regarding the hazards of contact with cold surfaces (e.g., cold burns). PPE (e.g., gloves, insulated clothing) should be provided.
		Exposure of personnel to chemical substances, fuels, and products containing hazardous substances	• Facilities should be equipped with a reliable system for gas detection that allows the source of release to be isolated and the inventory of gas that can be released to be reduced. • Liquefaction facilities with gas treatment operations may have the potential for releases of hydrogen sulfide (H_2S). Development of a contingency plan for H_2S release events, including appropriate aspects from evacuation to resumption of normal operations.

Source: JICA study team

12.8 Monitoring plan for the priority scenario

The proposed monitoring plan for the transport and supply of natural gas in the form of LNG from Dar es Salaam to Dodoma is shown in Table 12.8-1.

The purpose of monitoring is to: (1) verify that mitigation measures are being properly implemented; and (2) periodically collect information on changes in environmental conditions to verify that there are no environmental impacts caused during the implementation phase of the Plan. It is assumed that the monitoring will be carried out in cooperation with the HSE unit (hygiene, safety and environmental unit) of the TPDC and the division in charge of the operation of the respective facilities, and the results of the monitoring will be reported to the HSE unit.

The detailed monitoring plan at the time of implementation of this plan will be implemented based on the items discussed in the Project EIA and the Environmental and Social Control Plan (ESMP) according to individual projects with reference to Table 12.8-1.

1) Construction Phase

Table 12.8-1 Potential Monitoring items for Priority Scenarios (Transporting Natural Gas from Dar es Salaam to Dodoma in the form of LNG) in the Construction phase

Category	Potential Impact	Parameters to be monitored	Location	Measurements	Frequency	Responsibility
General	Inspection of mitigation compliance	General compliance with mitigation measures presented in the Environmental and Social Management Plan (ESMP) and as specified in the contractor document	Project activity areas	Visual inspection of all active work areas	Daily	Contractor
Ambient Air	Dust Generation	PM10	Identified air sensitive receptors within 200m from the construction sites	12-hours	Twice a year	TPDC
	Vehicle dust	PM10	Identified air sensitive receptors within 100m from the activity areas	12-hours	Twice a year	TPDC
Water Pollution	Occurrence of storm water	Storm water levels during construction	Neighbouring areas of the site	Visual inspection	Once a month	Contractor
Waste	Solid waste management	Appropriate collection, transport and management	Waste collection sites in project activity areas	Visual inspection of waste collection sites, and confirmation of proper disposal	Daily	Contractor

Category	Potential Impact	Parameters to be monitored	Location	Measurements	Frequency	Responsibility
	Spillage of oil and any hazardous material	Oil and fuel spills	Project activity areas	Visual check	Daily	Contractor
Noise & Vibration	Increased noise disturbance/vibration	Noise and vibration levels in Leq, Leq day, Leq night and hourly Leq	Identified sensitive receptors within 200m from construction sites	12-hours	Twice a year	TPDC
Odour	Wastes during construction	Odour from wastes not properly managed at site	Conduct proper management of wastes.	Visual check	Daily	Contractor
Bottom Sediment	Erosion of soil during construction	Spill over of eroded soil during construction	Properly plan and manage use of heavy machines at the construction site.	Visual check	Based on occurrence	Contractor
Topology and Geographical Features	Land reclamation during construction	Topology change by land reclamation	Minimize topology change by minimal land excavation and transfer of soil.	Visual check	Monthly	TPDC
Soil	Acceleration of soil erosion	Soil erosion tendencies	Project activity areas	Visual check	After every rainy season	Contractor
Resettlement (if necessary)	Relocation/compensation cost	Progress of resettlement	Affected communities	Progress of resettlement	Monthly	TPDC
	Complains regarding land acquisition and resettlement such as compensation, land use conflicts and water use conflicts	Complains in Grievance Redress Mechanisms (GRM)	Affected communities	Complains in GRM	Monthly	TPDC
Indigenous peoples and ethnic minorities.	Increased pressure on social services and resources indigenous peoples and ethnic minorities use	As per Indigenous People Plan.	Affected communities	As per the grievance redress mechanism	As per the grievance redress mechanism	As per the grievance redress mechanism
Community Infrastructure and Public Services	Increased visits of construction workers to local health services	Pressures on health services in the neighbouring areas.	Affected communities and neighbouring communities	Interviews with local health services	Based on occurrence	TPDC /Contractor
Employment and Economy	Increased local market opportunities	local market opportunities	Affected communities and neighbouring communities	Interviews with local people and relevant authorities	Once a year	TPDC /Contractor
	Increased local employment	local employment	Affected communities and neighbouring communities	Interviews with local people and relevant authorities	Once a year	TPDC /Contractor
	Increased pressure on social services	Complains from communities	Affected communities	As per the grievance redress mechanism	As per the grievance redress mechanism	As per the grievance redress mechanism
Cultural Heritage	Discovery of cultural heritage	Discovery of possible cultural heritage	Construction site	Visual inspection	As per occurrence	Contractor
Landscape	Impacts by use of heavy	Complaints	Construction site	Visual inspection	As per	Contractor

Category	Potential Impact	Parameters to be monitored	Location	Measurements	Frequency	Responsibility
	equipment and construction vehicles				occurrence	
Community Health and safety	Increased crime and insecurity	Crimes and complains	Affected communities	Crimes and complains	Based on occurrence	TPDC /Contractor
	Increase risks, hazards and accidents	Accidents, incidents and complaints	Affected communities	Incidents, accidents and community complaints	Based on occurrence	TPDC /Contractor
	Increased risk of HIV/AIDS and other STDs	Prevalence of STDs	Workers and Affected communities	Health check described in Health & Safety Plan to be prepared	Yearly	TPDC /Contractor
Occupational Health and Safety	Increase risks, hazards and accidents	Near-misses, incidents, occupational diseases, dangerous occurrences	Project activity areas	As defined in construction phase Health & Safety Plan to be prepared	As defined in H&S Plan	Contractor

Source: JICA study team

2) Operation Phase

Table 12.8-2 Potential Monitoring items for Priority Scenario (Transporting Natural Gas from Dar es Salaam to Dodoma in the form of LNG) in the Operation phase

Category	Potential Impact	Parameters to be monitored	Location	Measurements	Frequency	Responsibility
General	Inspection of mitigation compliance	General compliance with mitigation measures presented in the ESMP and operational manual	Project activity areas	Visual inspection of all active work areas	Daily	TPDC
Air Emissions	Emission concentrations	NOx	Emission point	Standard analytical methods	Annually	TPDC
	Ambient air quality	1-hour and 24-hour averaged NO_2	Identified nearby air sensitive receptors	Standard analytical methods	Annually	TPDC
GHG Emissions	Climate change	GHG generation	Plant control room	Natural gas consumption	Annually	TPDC

Category	Potential Impact	Parameters to be monitored	Location	Measurements	Frequency	Responsibility
Water	Impaired surface water quality	Turbidity, pH, DO, TSS, Total dissolved solids, oil & grease, total coliform, heavy metals	At wastewater discharge point	Standard analytical method	Quarterly	TPDC
	Impaired ground water quality	Depth, pH, salinity, NH +4, total P, heavy metals, oil & grease, BOD, COD and Total Coliforms	Neighbouring wells and boreholes	Standard analytical methods	Half Yearly	TPDC
Waste	Solid waste management	Appropriate collection, transport and management	Waste collection sites in Project activity areas	Visual inspection of all waste collection sites and confirmation of proper disposal	Daily	TPDC
Noise & vibration	Increased noise and vibration disturbance	Noise and vibration levels in Leq, Leq day, Leq night and hourly Leq	At Project boundary and at nearest sensitive receptors	24-hour	Quarterly	TPDC
Soil	Soil contamination	Leakage at the tank site and oil products storage	Project site	Visual inspection	Monthly	TPDC
Terrestrial ecology	Fauna strike along the LNG transportation route	Habitats and Disturbance to terrestrial species	LNG transportation route	Fauna strike incidents	Once a year	TPDC
Indigenous peoples and ethnic minorities.	Increased pressure on social services and resources indigenous peoples and ethnic minorities use	As per Indigenous People Plan.	Affected communities	As per the grievance redress mechanism	As per the grievance redress mechanism	As per the grievance redress mechanism
Employment and Economy	Increased local market opportunities	local market opportunities	Affected communities and neighbouring communities	Interviews with local people and relevant authorities	Once a year	TPDC
	Increased local employment	local employment	Affected communities and neighbouring communities	Interviews with local people and relevant authorities	Once a year	TPDC
	Increased pressure on social services	Complains from communities	Affected communities	As per the grievance redress mechanism	As per the grievance redress mechanism	TPDC
Community Infrastructure and Public Services	Increased visits of construction workers to local health services	Pressures on health services in the neighbouring areas.	Affected communities and neighbouring communities	Interviews with local health services	Based on occurrence	TPDC

Category	Potential Impact	Parameters to be monitored	Location	Measurements	Frequency	Responsibility
Community Health and safety	Increased crime and insecurity	Crimes and complains	Affected communities	Crimes and complains	Based on occurrence	TPDC
	Increase risks, hazards and accidents	Accidents, incidents and complaints	Affected communities	Incidents, accidents and community complaints	Based on occurrence	TPDC
	Increased risk of HIV/AIDS and other STDs	Prevalence of STDs	Workers and affected communities	Health check described in Health & Safety Plan	Yearly	TPDC
Occupational Health and Safety	Increase risks, hazards and accidents	Near-misses, incidents, occupational diseases, dangerous occurrences	Project activity areas	As defined in construction phase Health & Safety Plan	As defined in H&S Plan	TPDC
	Noise and vibration generation by Plant equipment	Sound pressure level	1m from the noise and vibration generating equipment	Noise and vibration monitor	Once a year	TPDC

Source: JICA study team

12.9 Stakeholder consultation

In SEA Regulation 2008 of Tanzania, the major participants of the consultation are as follows. The Division of Environment of the Vice President's Office (DOE-VPO) is to be involved in coordinating the consultation.

- Sector Ministries and Agencies
- Government agencies and departments
- Local government

In consideration of the above and discussions with TPDC, JICA Study team explained outline of the project and comparison of alternative scenarios to the following organizations and obtained their comments at the symposium held in January 2020.

Table 12.9-1 Target Organizations for Stakeholder Meetings in this study

	Category	Institutions
1	Sector Ministries and Agencies	• Ministry of Energy (MOE): Sector Ministry
2	Relevant government agencies and departments	• Tanzania Petroleum Development Corporation (TPDC): Implementing Agency • Ministry of Land and Human Settlement and Housing Development (MLHHSD)
3	Local government	• Regional Administration and Local Government, Prime Minister's Office (PMO-RALG)
4	Environmental administrative agency	• Division of Environment, Vice-President's Office (DOE-VPO) • National Environmental Management Council (NEMC)

Among major comments of participants, it was requested to ensure safety measures by establishing safety management standard so that risk management should be implemented properly. In addition, it was pointed that this project will contribute to contain deforestation by switching use of traditional energy such as firewood and charcoal to natural gas. Comments of participants were in principle positive on this project.

12.10 Points to be noted and Issues to be considered in Implementing Priority Scenarios

12.10.1 Project Implementation and obtaining EIA certificate

The Tanzanian EIA system is defined by the National Environmental Policies (1997) and the Environmental Management Act 2004. The EIA and the Environmental Impact Assessment and Audit Regulations, 2005 stipulate detailed implementation regulations based on the EMA, and the EIA is to be implemented in accordance with these regulations.

Regarding the energy sector, EIA implementation is mandatory in the following projects according to First Schedule of the "EIA and Environmental Audit Regulations 2005".

- Production and distribution of electricity, gas, steam and geothermal energy
- Storage of natural gas
- Thermal power development
- Hydro-electric power
- Development of other large scale renewable and non-renewable sources of energy

This would require EIA implementation in projects related to gas storage, supply, and production. However, final decisions on the need for EIAs are made by submitting a Project Brief to NEMC and their screening.

The EIA process in Tanzania is defined as follows by Environmental Impact Assessment and Audit Rules 2005. Table 12.10-1 summarizes the expected EIA schedule for project implementation, and Table 12.10-2 summarizes the outline of each step.

Table 12.10-1 EIA Steps and Assumed Schedules for Project Implementation

	Step	Responsible body	Months										
			1	2	3	4	5	6	7	8	9	10	11
1	EIA registartion	TPDC	■										
2	Screening	NEMC		■									
3	Scoping Report	TPDC/EIA Consultant			■								
4	Approval of Scoping Report	NEMC				■							
5	EIA study	TPDC/EIA Consultant				■	■	■	■				
6	Submission of EIA report to NEMC	TPDC							■				
7	EIA report review	NEMC and TAC								■	■		
8	EIA report modification	TPDC/EIA Consultant									■	■	
9	Approval of EIA certificate	Minister										■	■

Source: JICA study team

Table 12.10-2 EIA Process in Tanzania

Processes	Outline
Registration of projects	The proponent is required to register a project with NEMC by submitting duly filled EIA application form.
Screening	Screening is an initial review step in the EIA process. Thus, the EIA application forms and Project Brief are screened in order to assess and establish the category of project and determine the level of EIA required.
Scoping	If a full EIA is required, identification of main issues of concern through scoping will be conducted by the developer through Consultant. This is done by consulting the relevant concerned parties. Draft terms of references (ToR) will then be prepared to guide the impact assessment study. A Scoping Report and draft Terms of Reference (ToR) are submitted to NEMC for review and approval.
Impact assessment	Conduct EIAs based on TORs approved by NEMC. An important part of the EIA should be to identify possible impacts, assess the extent of the impacts, and propose appropriate mitigation measures to avoid, minimize negative impacts and maximize

Processes	Outline
	benefits. The output at this stage is an EIA report (or Environmental Impact Statement: EIS). The EIA Report includes an Environmental Management Plan (Environmental Management Plan) and a Monitoring Plan (MP) that summarize the management and monitoring methods for possible impacts. In addition, it is essential to hold explanatory meetings for residents when implementing EIA, and project implementers are required to hear opinions from key stakeholders.
Review	After the project proponent submits the EIA report (EIS), the NEMC implements the project site visit. This site visit is performed to verify the information of the EIA report. The NEMC will then coordinate the Technical Advisory Committee: TAC to review the EIA report. In response to comments from the NEMC, the Minister responsible for environmental decides to approve or disapprove the EIA report.
Public hearing	As part of the review process, public briefings may be needed to address public concerns about planned projects. The need for public briefings may also arise when there are major concerns from residents, depending on the location of the project site, the type and size of the project, the technology used, land use, relocation, cumulative impacts, etc.
Environmental decision-making	After submission of the final version of the EIS, NEMC assesses it in order to ascertain whether all the TAC comments and recommendations have been adequately addressed by the consultant. Thereafter terms and conditions for issuance of the EIA Certificate are prepared by NEMC. Approval/disapproval of the EIS is done by the Minister responsible for Environment as stipulated in EMA 2004.
Appeals	Both the proponent and the affected or interested parties have the right to appeal. If there is dissatisfaction on the decision reached, provision for appeal to the Environmental Tribunal or Court of law is provided by law.
Project implementation	Implement the project in accordance with the Environmental Management Plan (EMP) and Monitoring Plan (MP) based on approved conditions.
Monitoring	Monitoring is performed by project proponent and compliance monitoring is performed by NEMC and key stakeholders.
Environmental Audit	There are two types of environmental audits: Environmental Impact Audit, which compare the actual status with the impacts projected in the EIA report after project implementation; and Environmental Management Audit, which confirm compliance with plans, mitigation measures, and general compliance.

Source: JICA study team

In addition to the EIA licensing, other licenses related to project implementation in the priority scenario are as shown in the following table.

Table 12.10-3 Other Permissions Related to Project Implementation

Licensing	Explanation
Land Use permit	When the TPDC installs facilities such as Mini-LNG and LNG satellites, it is required to obtain land-use permission from the site where the LNG satellites are installed.
Permit to use Road Reserve	When installing gas pipes in road reserve, the operator (TPDC) must apply for permission to use the road reserve and obtain permission from the TANROADS or local government or other competent agency in order to construct gas pipes in accordance with the Road Law 2007.
Safety Inspection Permit	This is a license required for the construction stage and operation in accordance with

Licensing	Explanation
	the Industrial Safety and Health Law 2003.
Building Permit by Local Government	When the operator (TPDC) builds facilities such as Mini-LNG and LNG satellites, they shall apply for construction permission to the local governments where the facilities are located, and obtain the permission by the time of commencement of construction.
Permission to transport heavy goods from the port of entry to the site	When very large and heavy equipment, facilities, etc. are transported, the transportation authorization is obtained by paying the weight bill charged by the TANROADS. Contractors must obtain this license prior to transportation through TPDC.

Source: JICA study team

12.10.2 Other points to be noted in project implementation

1) Land acquisition and compensation

Projects in priority scenario do not anticipate large-scale land acquisition, but new land acquisition may be necessary when installing facilities such as LNG satellites or when developing access roads. The World Bank's Safeguard Policy (OP 4.12), referenced by JICA Guidelines, requires to establish a Resettlement Action Plan (RAP) in the event of involuntary relocation. If the scale of resettlement is small, an Abbreviated Resettlement Action Plan (ARAP) is to be prepared. IFC's PS5 also requires project proponent to develop and implement RAPs or Livelihood Restoration Plan for acquiring land and involuntary resettlement.

Tanzanian national law provides legal framework on compensation for land acquisition, but does not provide the preparation of RAPs. For this reason, when RAPs are prepared in a project, they are usually prepared to meet the requirements on environmental and social considerations by the project financing institution. In addition, if the exact boundary of the project site to be acquired is not determined, the Resettlement Policy Framework (RPF) is to be prepared, which is a policy document for compensation and implementation of resettlement. After the boundary is finalized, the compensation cost will be assessed by valuation and the RAP will be prepared based on the RPF.

There are differences between the compensation policies of the JICA Guidelines as well as the World Bank's safeguard policy and the compensation standards in Tanzania's national law. Among these differences, when assessing compensation costs for houses and other buildings, the national law assesses the compensation cost by applying depreciation. However, the international standard does not apply depreciation for structures. It is advisable to discuss and agree in advance with project proponent in order to deal with the differences in the policies for compensation in specific implementing projects based on this plan.

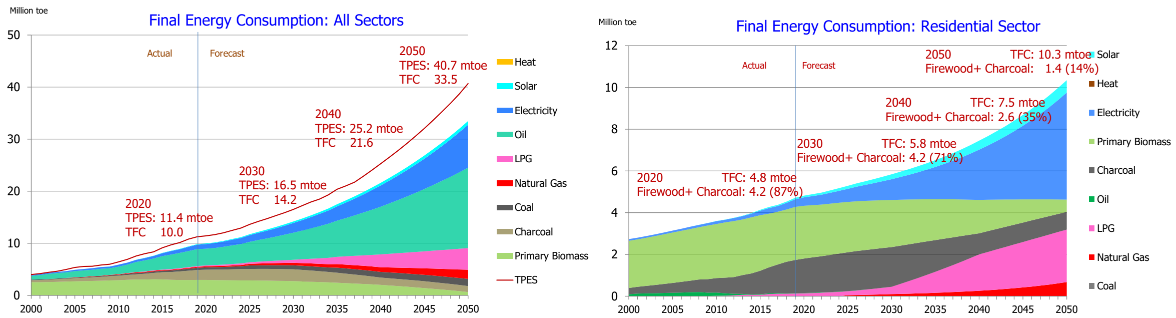
2) Raising awareness of safety and health issues and providing explanations to local people

When power plants and other facilities are planned, there may be concerns about wastewater, noise/vibration, waste generation, etc. from neighbouring residents. It is desirable for project proponent to provide opportunities to explain the project plan such as facilities, how to address the local people's concerns, and to build good relationships with neighbouring residents in advance. In Tanzania, understanding of the safety and hazards of gas is not so widely promoted, and related regulations are also being developed. Therefore, it is necessary to raise awareness of the hazards of natural gas through awareness-raising activities and training.

Chapter 13 Way Forward to Materialising DNGPP

13.1 Energy Consumption of Tanzania and Significance of Natural Gas Introduction

According to the estimation by the Study Team, total energy consumption of Tanzania was about 10 million tons oil equivalent, a half of which was used by the residential sector. Traditional fuels such as firewood and charcoal comprised 87% of the energy consumption in this sector. Energy consumption will continue to grow in accordance with population increase, economic growth, improving quality of life, urbanisation, and motorisation. Although its growing speed has temporarily slowed down due to the COVID-19 pandemic that shocked the world economy, energy consumption of Tanzania will continue to grow and the total primary energy supply (TPES) will exceed 40 million tons oil equivalent by 2050.



Source: JICA Study Team

Figure 13.1-1 Long Term Energy Outlook of Tanzania

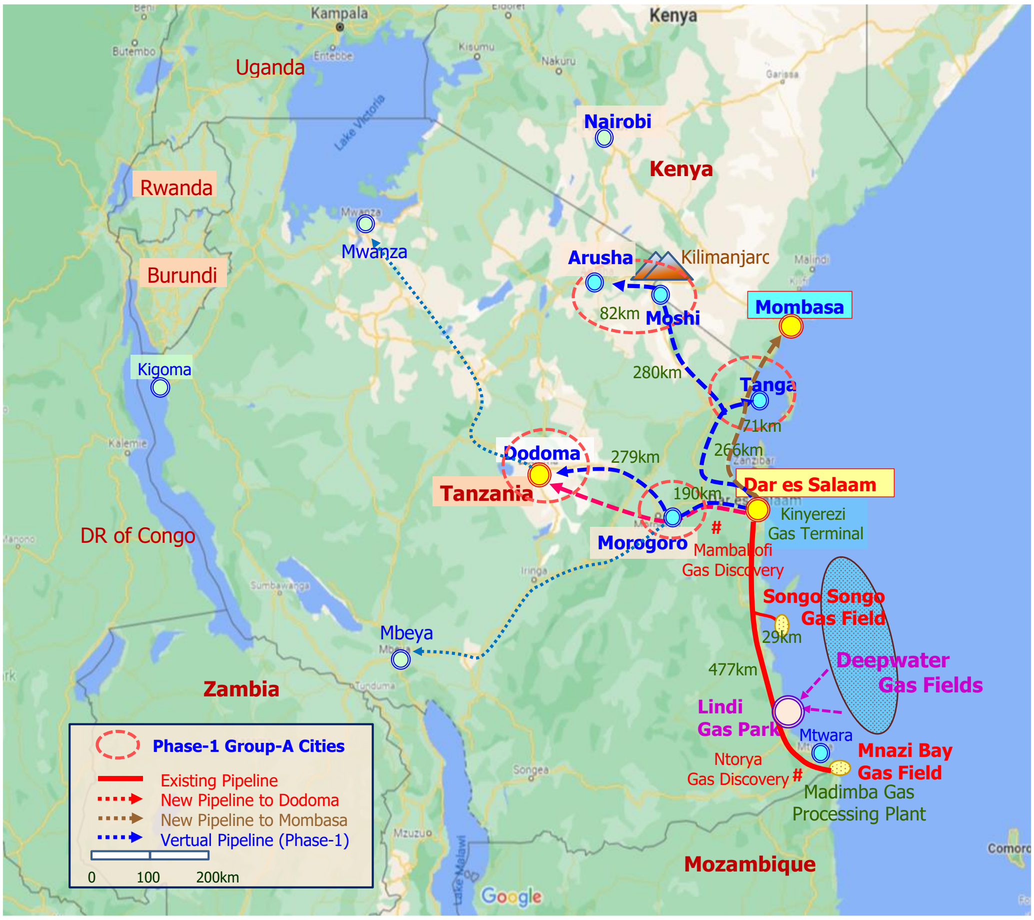
Energy consumption of Tanzania is presently less than 2% of that of Japan while heavily depending on traditional biofuels such as firewood and charcoal. It is not possible to develop the economy keeping the present energy structure nor leapfrog from this status to a modern economy based on variable renewable energies. Among others, it is an urgent issue to switch residential fuel from firewood and charcoal to gas, and reduce work to collect them, improve household air quality and curb deforestation. The right and practicable pathway is to establish modern energy infrastructure utilising natural gas at maximum, which is available, relatively clean and environment friendly, and then try to decarbonise it in future with introduction of modern biogas, methanation and/or construction of hydrogen network.

Under the circumstance, the Natural Gas Utilisation Master Plan (NGUMP) final draft released in 2016 proposed to utilise the natural gas resources found in the coastal regions and the deepwater, develop large scale gas industries, typically LNG, and also deliver natural gas nationwide. Thus, we carried out this study with an aim to establish a practicable plan to deliver natural gas to Tanzanian citizens. Since the south-eastern provinces up to Dar es Salaam are already covered by the existing pipeline, we examined gas transport methods beyond this area.

Usually, pipeline is used for transporting natural gas. If sufficient demand is secured, there is no doubt.

However, present regional energy markets in Tanzania are relatively small and distributed over the vast land. Starting from the present status, we may need to wait many years before the regional demand grows enough to take up this popular method.

The most plausible solution to overcome such status will be construction of pipelines combined with gas-fired power plants at major destinations. In the world history, gas and power have been developed in combination. Energy demand is not so large in the areas beyond Dar es Salaam. Unless any new gas-power plant comes up, construction of gas pipeline would not be feasible. We conducted this study under such circumstance and reported our findings at the symposium held in January 2020 that mini-LNG based *Virtual Pipeline* system is the most effective and practicable solution to distribute natural gas in the interior energy markets.



Source: JICA Study Team on Google Map

Figure 13.1-2 Pipeline or Virtual Pipeline for Tanzania

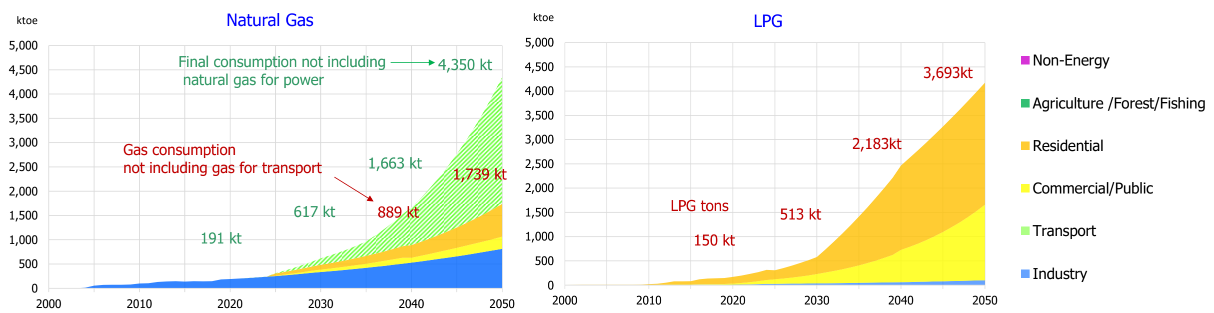
Since then, there have been several important developments. The Power System Master Plan (PSMP) 2020 Update announced in September 2020 schedules construction of two gas power plants at Dodoma and Bagamoyo; in view of the consumption volume, they will require extension of the existing pipeline. In May 2021, the pipeline construction plan was agreed between Tanzania and Kenya to link Dar es Salaam and Mombasa. These pipelines will open up a new possibility to supply natural gas along the route and at the destination. Thus, it is necessary to reassess the overall supply system taking account of the new developments on the backbone pipeline plan.

As the study outcome is encouraging on adoption of virtual pipeline, the gas sale plan considered for the project evaluation includes yet a lot of uncertainties. Natural gas use in Tanzania is presently confined to the regions along the existing pipeline. The speed of natural gas penetration into other areas will be affected by various factors. Many issues need firm back-up by the national energy policy such as speed of constructing gas supply system, support for procurement of gas utilisation equipment and appliances, availability of technical service, provision of affordable gas price, etc.

Gas demand is expected to grow and reach a significant volume in the long run. Energy consumption in the business/commercial sector and the residential sector will be switched from firewood to charcoal, and then to gas. As shown in Figure 13.1-1, we expect that the consumption of traditional fuel in the residential sector will come down below 15% by 2050. Natural gas use for city gas is assumed to start in 2025 at 50 ktoe in the residential sector and 5 ktoe in the business/commercial sector; this will double by 2030 and then continue grow at annual 10%. However, this penetration speed is an assumed scenario not having any back-up by firm policy. We also would like to note two points as below:

1) According to the above projection, natural gas will remain at around 20% of the total gas demand even in 2050, and the balance needs to be supplied with LPG. City gas grid can be developed only in the areas with certain demand density; such objective areas must be identified one by one on the candidate markets. Also, to accommodate robust increase of LPG consumption, it is necessary to prepare appropriate world-class systems for LPG import and domestic supply.

2) In the scenario to promote introduction of natural gas vehicles, it is assumed that about 15% of motor vehicles will be converted to natural gas by 2050. Then, the natural gas demand of the transport sector will increase far greater than that consumed by business/commercial and residential sectors. However, this is yet not more than a preliminary calculation.



Source: JICA Study Team on Google Map

Figure 13.1-3 Preliminary Estimation of Gas Demand

Natural gas supply of the final energy consumption sectors, excluding use for power generation and feedstock for gas-based industries, will increase replacing potential LPG import. It will replace $0.5 billion in 2030, $0.9 billion in 2040 and $1.7 billion in 2050. However, the assumed penetration speed is relatively modest against the demand growth for gaseous fuel. Thus, import of LPG will expand robust exceeding 70% of the total gaseous fuels requirement as shown in Table 13.1-1. LPG import bill will increase near to $2 billion in 2040 and exceed $3 billion in 2050. LPG will be necessary to supply gas for rural distributed minor consumers. But accelerating NGUMP with proactive policy action, much more LPG import will be replaced.

In addition, introduction of natural gas vehicles will also have a great impact. Slowly in the early decades, but it will accelerate with motorisation and will eventually reduce oil product import bill by more than $2 billion in 2050.

Table 13.1-1 Potential Demand of Gas and Import Bill

	2030	2040	2050	2030	2040	2050
	ktoe	ktoe	ktoe	$ billion	$ billion	$ billion
Natural Gas replacing LPG Import	**485**	**889**	**1,739**	**0.3**	**0.7**	**1.4**
LPG Import	**580**	**2,467**	**4,173**	**0.3**	**1.8**	**3.3**
LPG Share over total Gas Fuel	54%	73%	71%			
NGV to replace Oil Import	**132**	**774**	**2,611**	**0.1**	**0.6**	**2.3**

Source: JICA Study Team

Though the above scenarios contain high uncertainties, if materialised, introducing clean gas fuel, significant benefit will be brought for improvement of environment such as cleaner domestic air and emissions reduction in use of motor fuel as well as reduction of foreign currency outflow required for import of LPG and petroleum products. The effect is great, but the threshold is high for natural gas switching particularly in the initiation stage. It would not come up spontaneously. Therefore, it is required for the government to hammer out a tangible plan such as to start city gas system from the densely populated areas and expand it in turn, develop LNG corridors and enhance introduction of natural gas vehicles, etc., waving the flag with enthusiasm.

Among others, the Study Team thinks that it is necessary to secure firm anchor demand enough to assure that the gas supply system will become surely competitive and resilient. This will be achieved by introducing challenging projects such as discussed below, which will provide considerable demand. On the other hand, there is a plan to extend the existing pipeline to cover existing and emerging energy consumers in Pwani Region (see section 5.7). These will in turn require high level consensus on the national energy policy. Under the circumstance, the Study Team proposes conduct of Framework Study on these issues, decide selection of options, and set forth key principles and priorities under the National Gas Development Plan as the backbone for developing natural gas supply system in Tanzania.

13.2 Priority Issues to be Considered

At present, despite the encouraging outcome, even the virtual pipeline system is not readily viable in Tanzania. For materialisation of the DNGPP, major issues are identified in this study as follows:

1. Issues on Project Formulation
   a. Though gas demand is expected to grow in the middle to long run, prospective gas demand for the early stage is very small and fragile for justification of a competitive and resilient project.
   b. Upfront expenditure is necessary for construction/conversion of equipment, purchase of gas appliances, purchase of NGVs and/or gas-conversion of vehicles. For minor users such as small shops and households, costs for connection ($1,000 ~1,500) and purchase of gas appliances are high, and would invite hesitation.
   c. For promotion of NGVs, it is necessary to develop network of natural gas service stations to solicit NGV users.
2. Concerns on Project Implementation
   a. For customers switching to gas, service network of supporting industries for installation, operation and maintenance needs to be developed:
      - Technical service for city gas equipment and operation: medium/large users
      - Gas appliance shops: small/medium users
      - L-CNG stations for NGVs
      - Auto-workshops for NGVs
   b. Creation of proper workforce is necessary for the gas supply sector as well as the customer service sector.
   c. Laws, regulations, and promotion policies on safe and efficient gas industry as well as an implementation body of these need to be set out under a comprehensive and coherent system

Examining these issues, the government is required to show a firm gasification plan including clear concept of each project, priority of projects and the overall roadmap under the National Gas Development Plan. We discuss major issues and candidate solutions as below.

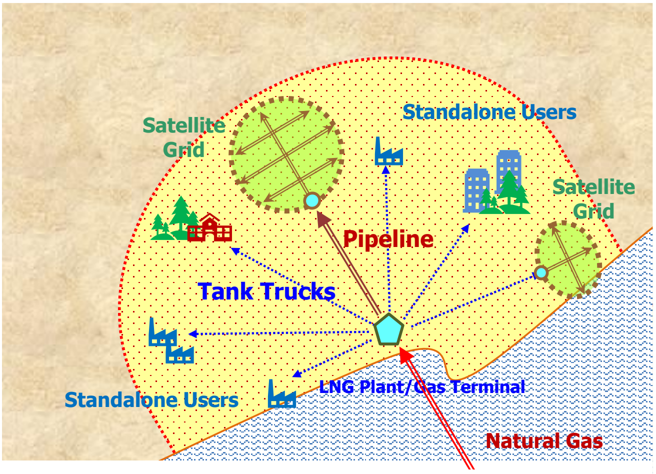
13.2.1 Prospect of Gas Demand

Compared with pipeline that can serve users at the destination and along the pipeline route only, *virtual pipeline can pick up energy users scattered in multiple directions*. Thus, it can consolidate isolated users in multiple locations and create an integrated market for natural gas supply. Nevertheless, our study further shows that the existing energy demand in interior areas of Tanzania is presently small and fragile even for the virtual pipeline plan. This is mainly because of the mini-LNG plant cost, which is subject to economies of scale. While the gas demand in the early stage of the project is estimated to be about 60,000 tons in LNG equivalent (Table 12.1-1; 61,300 tons for 2030), it is desirable to select a plant size of at least 200 tons, hopefully 300 tons, per day times 2 trains; annual production of 132,000 tons or 198,000 tons. Two trains are scheduled at the LNG plant for assurance of stable operation. In contrast, a real pipeline may need at least 600,000 tons a year in LNG equivalent for moving natural gas at a competitive cost for 500km.

Adopting virtual pipeline, some additional demand that will provide anchor demand in the initial stage is necessary to justify the project. In this regard, several options to create material demand should be considered such as;

a. Switching obsolete power stations running on diesel to gas, such as the one in Zuzu in Dodoma.
b. Construction of small-medium scale CHP (combined heat and power) plants (5-50 MW) to use gas as district energy system or energy platform for industrial parks.
c. Introduction of natural gas vehicles (NGVs) and development of gas service station network. As LNG-based gas station can serve natural gas for vehicles in both form of LNG and CNG, construction of LNG corridors should be considered.

Save for construction of ordinary scale gas power plants, each option will give significant impact on gas development. At the same time, all of them have challenging aspects to require high-level political decisions. At any late, introduction of natural gas is expected to bring about robust fruitage for the national economy such as economic development with environment friendly energy, stable power supply, reduction of foreign currency out-flow and promotion of new natural gas vehicle industry. Under the circumstance, it is necessary to establish a national consensus on these options. To this end, we propose to formulate the National Gas Development Plan in the next step to decide the concrete plan examining various aspects of these options. To establish an affirmative demand plan, many complicated issues must be solved. However, once a firm business platform is established, the Study team trusts that stones start rolling and such gas distribution system will be developed nationwide as the backbone of the energy supply system of the country.



Source: JICA Study Team

Figure 13.2-1 Pipeline vs. Virtual Pipeline

13.2.2 Gas Price and Mitigation of High Upfront Cost

From the findings of this Study,

a. Except for those users of cheap fuel such as heavy fuel oil, coal and petro-coke, virtual pipeline can offer attractive prices for large energy users at a comfortable margin, but customers may need technical services and financing for upfront expenditure.

b. Virtual pipeline can offer competitive gas prices for minor customers like small shops and households, but they may need technical service and support for upfront expenditure on inlet pipe connection and gas appliances.

c. Virtual pipeline can offer attractive fuel prices for NGV users, but they may need comfortable technical service and support on the upfront expenditure.

There will be several measures to solve these issues such as:

a. Exemption of import tax on gas equipment, gas appliances and NGVs including their parts. Import tax is generally about 50% in Tanzania and its exemption will have a significant effect on both supply and consumption sides.

b. Tax holiday and/or tax incentives for introduction of natural gas.

c. Provision of subsidy for purchase of equipment and appliances.

d. Provision of low interest loans for upfront expenditure, including instalment plan.

To implement these promoting policies, we need fund. To this end, we can consider cross-subsidy. As analysed in Chapter 11, replacing the imported petroleum products, substantial economic rent or surplus profit will be expected from the domestic gas utilisation project as a whole. In order to solve financial issues, Gas Development Levy may be set on the government take of the upstream production as well as the excess economic rent on the selected demand sectors. Then, special purpose funds such as City Gas Fund and NGV Fund may be created as below:

a. City Gas Fund to provide subsidies for construction of city gas system, pipe connection to minor users and capacity development of employees, as well as financing for upfront investment at users.

b. NGV Fund to provide subsidies for development of auto repair shop network and natural gas service station network, gas conversion of vehicles and capacity development of employees.

Once the program starts rolling, such fund can be collected from the proceeds of gas sales. At the starting, however, some fund must be prepared to finance the upfront requirement; it may need to cover several years until the fund collection system reaches a stable financial status. Such fund for the initial investment may be sought from the World Bank/IFC, African Development Bank, and export credit agencies and international cooperative agencies of cooperative countries (in case of Japan, JBIC and JICA, respectively) in the form of low interest loans and cooperative grants. Also, once the large scale LNG export project were confirmed, it will be possible to create loans based on long term LNG sale/purchase contracts.

13.2.3 Capacity Development on Technical Service

Proper technical services for gas users are yet to be prepared in Tanzania for introduction of natural gas such as:

a. Technical service for users' gas facilities and appliances

b. Natural gas service stations for NGVs

c. Technical service for NGVs.

In these fields mature and proven technologies are available in the world, but it may take some time to line up appropriate technical service system in Tanzania. For example, preparatory work is an issue. Suppose one pipe connection team completes pipe connection for 3 users a day or 1,000 users a year, to dig a ditch, lay down pipe, connect it to the domestic pipe and backfill, ten (10) teams are necessary to complete 10,000 connection a year. Similar number of auto repair shop teams will be necessary to convert cars and trucks. Vehicles may be converted in exporting countries before shipment, but it is desirable to create such industry within Tanzania.

Availability of qualified technical teams and their capability are critical to decide the speed of gas demand build-up. It will in turn affect the project economics seriously. Capacity development programmes may be sought from foreign countries. In view that a big workforce is necessary, lecturers should be trained up at first well in advance. Then, they will lead training courses in Tanzania to create various technical teams.

13.2.4 Laws and regulations

To implement the project, proper legal system and its implementation body must be prepared under a comprehensive project concept. Without having a history of gas use, it is necessary to review laws and regulations, set forth proper political directive and prepare appropriate business conditions. Issues to be examined will be;

a. Business framework of city gas industry, service industry for gas equipment and appliances, NGV stations, etc.

b. Preparation of proper laws, regulations and application procedure on safe gas use such as technical standard and regulation on high pressure gas handling and provision of construction code.

c. Qualification system of engineers and mechanics on gas equipment and operation, NGVs, etc.

d. Policy and institution to promote introduction of gas such as beneficial taxation, provision of low interest loans, guarantees and subsidies.

e. Creation of a public body to implement safety inspection and approval, qualification test and issuance of certificate, distribution of official aid, etc.

For reference on these issues, a summary report on the Japanese legal system on gas pipeline is provided in Appendix-E.

13.3 Roadmap for National Gas Development Plan

For construction of the national natural gas supply system, it is foremost important to *create a bankable plan*. With this in mind, key principles should be set forth under the National Gas Development Plan on selection of sectors to use gas and their priorities. Then, project size and development timeline will be figured out. Critical issues and work roadmap in this stage will be as illustrated below. Among others, it is foremost important to establish a model plan for future gas consumption including gas introduction plans at core users. Based on it, an implementation plan will be developed for each sector of the virtual pipeline.

13.3.1 Demand Creation

To start with, it is foremost important to establish a model plan for gas demand. To this end, candidate options as shown below by category should be examined and consolidated in a coherent manner.

1) Demand Creation Programme-1: power generation
   a. Gas switching of obsolete power stations such as Zuzu
   b. Independent power system to reinforce the security of the NGC and other cities
   c. CHP for regional energy system and/or industrial park energy platform

   To identify these optional power supply plan, following matters should be reviewed:
   - Possible position of these optional power generation in the Power System Master Plan
   - Development plans for cities and industrial parks
   - Price schedule by supply mode and quantity

2) Demand Creation Programme-2: LNG delivery for city gas and isolated users
   a. City gas plan for major cities
   b. Large isolated users for LNG direct delivery

   To identify plans of these gas users, it is necessary to prepare firm supporting plans on the following points:
   - Model plan for user's equipment, construction cost and time schedule
   - Technical services and user support plan
   - Price schedule by supply mode and quantity
   - Supporting policies for introduction of gas such as subsidies, loans, and tax exemptions
   - Relevant laws and regulations on technical standard, safety, and environment

3) Demand Creation Programme-3: natural gas service stations
   a. Development of LNG corridor with natural gas service stations

b. Development of local gas grids connected to natural gas service stations

To identify these plans, it is necessary to prepare firm supporting plans on following points:

- National automotive policy and NGV introduction plan
- Development plan of auto repair shop for gas conversion
- Model plan and cost for gas conversion of vehicles
- Price schedule for gas
- Supporting policies for conversion to NGVs such as subsidies, loans, and tax exemptions
- Relevant laws and regulations on technical standard, safety, and environment

13.3.2 Model Plan for Gas Supply System

Once an affirmative demand schedule is established, plans for supply side will be developed as follows:

a. LNG plant construction plan
b. LNG transport system development plan
c. City gas development plan
d. Price schedule for gas
e. Supporting policies for financing such as subsidies and tax exemption
f. Relevant laws and regulations on technical standard, safety and environment, and inspection and licencing procedures

From the findings of this Study, discussion will start with a model plan outlined as below:

a. A mini-LNG plant with 2 trains of 200 tons, or hopefully 300 tons plus, per day production capacity to be built at the Kinyerezi energy complex in Dar es Salaam
The plant will obtain its feedgas from the GASCO system at the Kinyerezi energy complex.
b. LNG will be sold to large bulk delivery users, natural gas service stations and city gas systems. LNG will be transported by trailer-containers with a payload of 18 tons.
c. City gas grids will be developed in Dodoma and other major cities.
d. Isolated gas users for LNG direct bulk delivery will build LNG receiving facilities and gas use equipment
e. L-CNG stations will be built according to the NGV introduction plan.

The above project specifications will be revised according to review of the demand schedule as discussed in 13.1.1. Once the overall plan is confirmed, special purpose companies will be established as vehicles to construct and operate the relevant sector as below.

a. <u>LNG Company</u>: for construction and operation of the LNG plant, and delivery of LNG for large users of direct bulk transport, natural gas service stations and the city gas companies. Among the functions of the LNG Company, LNG transport may be out-sourced to a transport company established separately in view of its specific business feature.

b. <u>City Gas Company</u>: for construction and operation of city gas systems in major cities. It receives, stores and regasifies LNG, and distribute city gas. It may also solicit direct bulk delivery users in its marketing territory.

c. Auto-Gas Service Company: for construction and operation of natural gas service stations for NGVs. It receives, stores and regasifies LNG, and serves LNG and CNG for NGVs.

In addition to the above, technical service companies will be established to back up introduction of natural gas such as:

a. Gas Shop: for sale and maintenance services of gas equipment and appliances for medium/small users. Such shops should be obligated to post an engineer with technical qualification on safe and efficient handling of gas equipment.

b. Energy Service Company (ESCO): for designing, construction, operation and maintenance of gas utilisation system at large users. In particular, handling of LNG and vaporiser needs technical expertise which is not readily available in Tanzania. Gas utilisation system may be sold or offered on lease fee basis. This service may be a part of the function of the city gas company. Offers of gas introduction with support of qualified technical team will ease anxieties at users.

c. Auto repair shops: for conversion and maintenance of automotive fuel system. Automotive dealers may import gas-converted vehicles or import oil-driven vehicles and convert them for gas use and sell NGVs.

13.3.3 Roadmap

The above various plans should be structured consistently under one framework. Consensus should be established among various sectors on the roadmap for development such as shown in Figure 13.3-1 and their roles. To this end, various work should be implemented as illustrated below.

1. Stage-1: Framework Study

At first, framework of the virtual pipeline plan should be established. Once demand size for the kick-off project is confirmed as per discussion in 13.2.1, an affirmative model project plan should be established. It should be a refined version of this Study and shall be endorsed by the National Gas Development Plan. Work on this stage will include investigation on the following items:

a. LNG plant plan, in particular the plant size and cost schedule
b. Model plans for large users on LNG receiving, storage and gasification facilities including costs for construction and operation.
c. Model plan for introduction of NGVs and developing a network of natural gas service stations
d. City gas development plans in major cities

At this stage, it is essential to set out firm supporting policies such as:

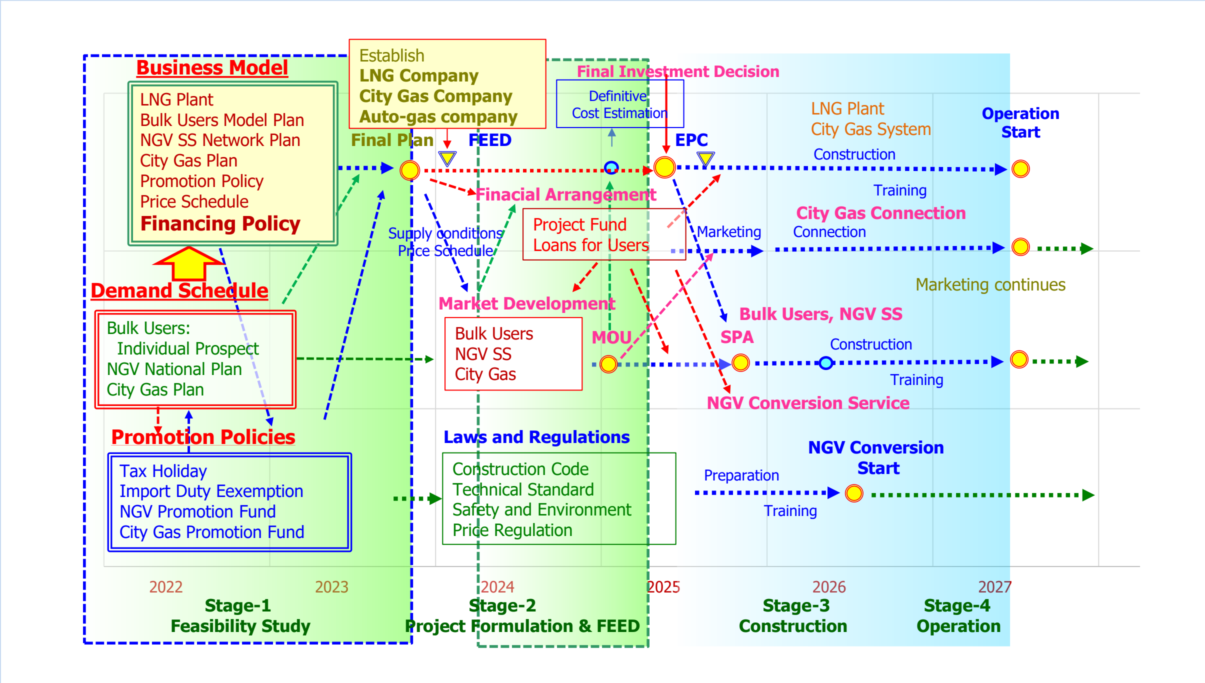
- Supporting plans for supply sector, LNG plant, transport, city gas and service providers, on business profitability, financing, business management and technical capacity development
- Promotion policies for large users in particular on economy of gas switching, financing upfront investment and technical support
- Promotion policies for small-medium users of city gas in particular on upfront payment for connection and purchase of appliances
- Promotion policy for NGV introduction in particular on economic benefit (import tax), financing of upfront payment and technical services

2. Stage-2: Project Formulation

Once the above Framework Study is completed, the project goes into the Stage-2 for project formulation. Various sectors should work consistently as shown in the road map in Figure 13.3-1. Major activities in this stage are as follows:

a. Project participants and financing structure will be finalised and project companies (LNG Company, City Gas Company and Auto-gas Company) will be established.
b. Above project companies shall set out gas sale conditions, price schedule and service programmes, and start soliciting customers. In particular, it is important to establish gas sale with large LNG users and long-haul fleet operators to secure large scale base demand for the project.
c. Project companies start FEED for construction of their facilities.
d. Start preparation of service companies for gas equipment and NGVs for gas conversion.
e. Government sector shall set out promotion policies, review and/or newly formulate laws, regulations and application procedures.

The project plan will be reviewed and refined with additional information obtained during the Stage-2. Once certain amount of prospective demand enough to ensure the project is confirmed and the financing plan is agreed, the project plan will be finalised among project participants and stakeholders. Upon the agreement, the project is almost confirmed. Based on the agreed project plan, FEED will be conducted on construction of LNG plant, city gas system and L-CNG stations. With affirmative outcome of the FEED, the financing arrangement will be finalised and the Final Investment Decision (FID) will be made.



Source: JICA Study Team

Figure 13.3-1 Roadmap for LNG-based Virtual Pipeline

3. Stage-3: Construction

Upon FID, the project goes into the Stage-3 or construction stage.

a. LNG plant, satellite terminals and city gas systems, users' facilities and natural gas service stations will be constructed.

b. LNG/gas sale purchase agreements will be signed with customers, while marketing will be continued further.

c. Upon completion of the city gas delivery pipe lay down, gas line connection will be made to individual users.

d. LNG containers and trailers will be procured.

e. Operators for the LNG plant, city gas system, natural gas service stations and technical service companies and truck drivers will be engaged, go through training programmes and obtain qualifications.

f. Auto repair shops starts gas conversion of vehicles.

4. Stage-4: Operation and Expansion

Once construction or procurement in all sectors are completed, the project starts moving. With successful implementation of the first project, the similar system will be rolled out to peripheral areas, other regions and other bulk delivery users. When sale of LNG increases closer to the initial supply capacity, new supply may be sought from an additional train to be built at Kinyerezi or a new large LNG plant to be built at Lindi.

In addition, spin-off effects of introducing LNG may be explored such as:

a. Rural electrification with distributed power stations using indigenous gas.
b. Construction of "cold-chain" using the cryogenic temperature of LNG such as cold storage warehouse or production of ice.
c. Others

13.4 Notes on Issues and Possibilities

13.4.1 Environment and Fuel of Quality

Introduction of natural gas is expected to mitigate environmental concerns in terms that it will reduce GHG emissions compared with combustion of other fuels and alleviate the accelerating deforestation replacing consumption of firewood and charcoal. It will also decrease time for collection of firewood, improve domestic air quality while cocking and reduce time for meal preparation contributing to improvement of gender related issues.

Some industries such as ceramics and glass need cleaner fuel like natural gas for the quality of their products. Non-energy intensive industries may prefer convenient natural gas, as it is easy to use only the necessary quantity at necessary time and hands-free to control like electricity and hence energy management is easier.

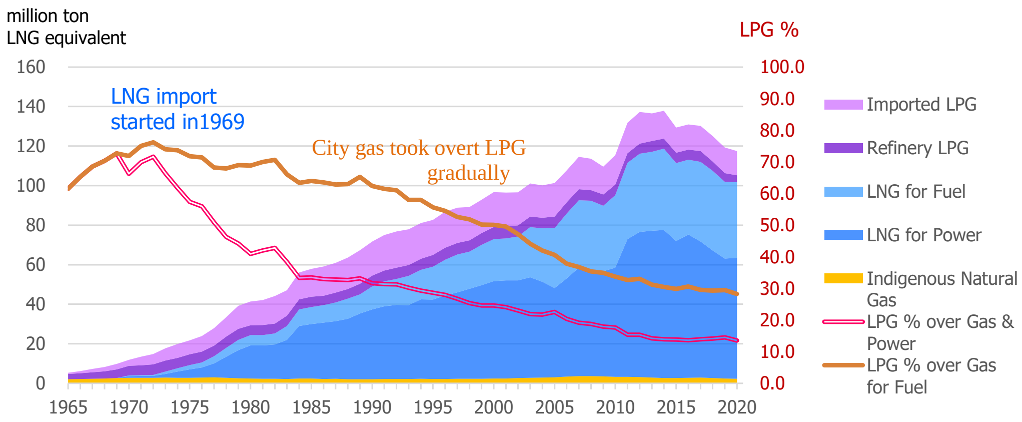
As far as issues on environment and fuel quality are concerned, natural gas is a preferred option.

13.4.2 Promotion of LPG

Implementation of the first natural gas supply project takes several years as explained above. Expansion of the system to other areas may occur only after that. Like electricity grid, city gas grid can be developed only in the areas where density of demand or settlement ratio is sufficiently high. Thus, we need to identify the boundary of city gas grid on each individual market. In not densely populated areas, natural gas delivery via city gas grid may come up considerably later or even would not occur. Rather, LPG may be preferred because of the convenience and economy of delivery.

In case of Japan, it took 15 years or more for natural gas to replace LPG even in the three metropolitan areas, Tokyo, Osaka, and Nagoya, since LNG import started in 1969; many more years were necessary to introduce LNG based natural gas into local cities. In China, where coal based city gas was historically available, switching to natural gas progressed relatively fast after 2000. However, LPG were adopted first in other Asian countries, and city gas is slow to develop. Even in natural gas producing countries like Brunei and Malaysia, city gas for residential sector is not developed well except for specific areas. On the other hand, governments of Indonesia and India implemented proactive policy to introduce LPG and successfully speeded up its penetration.

During the initial stage of LPG introduction, many accidents were experienced in South-east Asian countries caused by improper handling of used gas cylinders. In Tanzania where rapid penetration of LPG is expected, it is necessary to set forth safety regulations, qualification system (in Japan, high-pressure gas technical engineer), promotion policy to aid LPG introduction and so forth, and establish an official institution to promote awareness on safety and provide relevant services such as inspection and approval of equipment and appliances, qualification test and issuance of certificates, distribution of subsidies, etc. (in Japan, The High Pressure Gas Safety Institute of Japan, Japan LP Gas Association, etc.)



Source: JICA study Team

Figure 13.4-1 LPG Ratio over Gaseous Fuel in Japan

In view that gasification is an urgent issue for improving quality of life, it should be implemented at first by LPG in the areas where early introduction of natural gas is difficult. When natural gas based city gas becomes justifiable in these areas, LPG will be replaced in due course.

Use of LPG has started to increase in Tanzania only in recent years, and recorded 125 thousand tons in 2019. Although the present consumption volume is small, there is a high possibility as discussed in Chapter 5 that LPG consumption in Tanzania may exceed 500 thousand tons by 2030. As indigenous natural gas is very lean having a least content of propane, LPG must be imported from abroad. However, the present LPG import and distribution facility in Tanzania is yet poor. In order to accommodate increasing demand, it is necessary to develop an appropriate plan for construction of an international class import terminal, storage capacity and distribution system not only for Tanzania but also as a gateway for interior countries. As the baseline to nurture a healthy market, proper rules and regulations on control of quality and safety must be set out. Introduction of the ICT based efficient and accurate distribution system may also be considered for healthy market development.

All in all, to implement proper and orderly introduction of LPG, it is necessary to formulate a comprehensive plan covering the above mentioned issues.

13.4.3 Expansion of Virtual Pipeline for Neighbouring Countries

Once the above system is put on the stable development track, similar system may be extended to other regions and users. Export of LNG via same system to neighbouring countries may be considered. As shown in Table 13.4-1, fossil energy requirement in these countries is still low to justify construction of a trunk gas pipeline in the region. Until their energy requirements reach certain threshold, virtual pipeline by way of LNG will be preferred as a realistic option to serve clean energy to these countries. This will contribute to improvement of energy security, quality of life, environment and deforestation in East African countries.

Table 13.4-1 Energy Consumption in Neighbouring Countries (IEA): 2019

Primary Energy Supply	Pop	Coal	Oil	Natural Gas	Hydro	Geo-thermal	Solar/ wind	Biofuel & Waste	Electricity	Total	Excluding Biomass
	million	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe
Ethiopia	115.0	280	4,485	0	1,252	0	47	38,813	-86	44,792	5,979
Kenya	53.8	1,512	4,763	0	276	4,200	109	17,996	22	28,878	10,882
Tanzania	59.7	439	2,371	818	213	0	8	18,296	10	22,155	3,859
Mozambique	31.3	11	1,656	756	1,284	0	3	7,597	-214	11,092	3,495
Uganda	45.7	0	1,849	0	347	0	14	16,199	-24	18,385	2,186
Zambia	18.4	588	1,226	0	1,060	0	10	7,684	-67	10,501	2,817
Composition		%	%	%	%	%	%	%	%	%	%
Ethiopia		0.6	10.0	0.0	2.8	0.0	0.1	86.7	-0.2	100.0	13.3
Kenya		5.2	16.5	0.0	1.0	14.5	0.4	62.3	0.1	100.0	37.7
Tanzania		2.0	10.7	3.7	1.0	0.0	0.0	82.6	0.0	100.0	17.4
Mozambique		0.1	14.9	6.8	11.6	0.0	0.0	68.5	-1.9	100.0	31.5
Uganda		0.0	10.1	0.0	1.9	0.0	0.1	88.1	-0.1	100.0	11.9
Zambia		5.6	11.7	0.0	10.1	0.0	0.1	73.2	-0.6	100.0	26.8

Note: Population and GDP for 2020, World Bank. IEA's estimation of biofuel consumption tends to be too high as discussed in Chapter 5.

Electricity Balance	GDP per capita	Energy Input for Power Generation									Electricity Output
		Coal	Oil	Natural Gas	Hydro	Geo-thermal	Solar/ wind	Biofuel & Waste	Total	Fossil Fuel Total	
	$	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	TWh
Ethiopia	2,422	0	1	0	1,252	0	47	0	1,300	1	15.1
Kenya	4,576	0	365	0	274	4,200	109	0	4,948	365	10.5
Tanzania	1,076	0	472	706	213	0	0	31	1,422	1,178	7.8
Mozambique	1,297	0	30	621	1,284	0	3	0	1,938	651	18.8
Uganda	2,293	0	0	0	0	0	0	2,697	2,697	0	0.1
Zambia	3,456	478	138	0	1,060	0	10	0	1,686	616	14.7
Composition		%	%	%	%	%	%	%	%	%	Access
Ethiopia		0.0	0.1	0.0	96.3	0.0	3.6	0.0	100.0	0.1	48.3%
Kenya		0.0	7.4	0.0	5.5	84.9	2.2	0.0	100.0	7.4	69.7%
Tanzania		0.0	33.2	49.6	15.0	0.0	0.0	2.2	100.0	82.8	37.7%
Mozambique		0.0	1.5	32.0	66.3	0.0	0.2	0.0	100.0	33.6	29.6%
Uganda		0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	0.0	41.3%
Zambia		28.4	8.2	0.0	62.9	0.0	0.6	0.0	100.0	36.5	43.0%

Note: IEA's estimation for Uganda is tricky. Geothermal input is calculated assuming the generation efficiency of 9.5%, which would incur over-estimation of geothermal input. For example, the same is assumed at 100% for hydro and 33% for nuclear.

Source: IEA World Energy Balances 2021

13.5 Way Forward

Progress of natural gas utilisation is relatively slow in Tanzania. This may partly be caused by some anxieties in the background as below:

3) Developing large natural gas projects such as gas fired power stations and an LNG project, natural gas resources would be used up after 30 years.

4) Is it a right way to increase fossil fuel consumption as the world is moving toward a net-zero society?

Firstly, Tanzania is still in an early stage of natural gas exploration. As seen in the history of foregoing countries, the natural gas resources can be increased with future exploration activities[79]. If an oil company must wait more than 30 years to commercialise its discovery, nobody would invest in exploration. Natural gas to be used 20-30 years later can be explored and discovered from now. Geological potential is high. If effective demand were created, active players will show up, explore for and develop the resource base.

Secondly, energy consumption of Tanzania is presently less than 2% of that of Japan while heavily depending on traditional biofuels such as firewood and charcoal. It is impossible to leapfrog from this status to a modern economy solely based on variable renewable energies. The right and practicable pathway is to establish modern energy infrastructure utilising natural gas at maximum, which is available, relatively clean and environment friendly, and then try to decarbonise it in future with introduction of modern biogas, methanation and/or construction of hydrogen network.

As explained in this report, the Study Team presented its study outcome at the symposium held in January 2020 that, as a measure to distribute natural gas in the domestic energy market beyond the existing system in Dar es Salaam, *a mini-LNG based virtual pipeline system* is selected as the most preferable option. Since then, there are several important developments to consider the national gas supply system as below:

1) Sizable gas discoveries are being confirmed at Ntorya and Mambakofi in addition to the producing fields such as Songo Songo and Mnazi Bay. They are located onshore and close to the existing pipeline, and hence considered to be easy to develop for domestic gas supply. Viewing from the producers' side, on the other hand, it is necessary to create enough demand to encourage development of these gas fields including prospects around the producing gas fields.

2) The Power System Master Plan (PSMP) 2020 Update was announced in September 2020. It lists two gas power projects in the areas beyond the existing gas terminal in Dar es Salaam; Dodoma gas power station (600MW) to start in 2033 and Bagamoyo gas power station (300MW) to start 2040. In view of the volume of natural gas consumption, new gas pipelines will be extended to these sites.

3) In May 2021, Tanzania and Kenya agreed to construct a gas pipeline for 600km connecting Dar es Salaam and Mombasa.

4) The Study Team conducted additional energy demand survey: potential demand reading on the Google Map and market research by the team of the Ministry of Energy. All surveys including the Regional Energy Demand Survey (REDS) conducted in 2018 are confined to seven to eleven regions out of 26 regions all over the mainland Tanzania. However, information on the potential gas demand is not available for the rest of the country.

[79] According to the BP Statistical Review of World Energy, natural gas reserves in Malaysia was 19.7 Tcf in 1983 when the country began LNG export. By 2020, the country had consumed 63 Tcf of natural gas, while natural gas reserves at the end of 2020 increased to 32 Tcf; which do not include the resources under evaluation expected to be more than 10 Tcf.

5） Baker Botts, a prominent international law firm, was nominated as the Transaction Adviser to the Government Negotiation Team and TPDC regarding the development of the LNG project. This will accelerate development of the long-waited LNG project.

Under the circumstance, we may need to upgrade the present study outcome to a comprehensive national gasification plan incorporating these developments. Key points of the work will be as follows:

1） Basic position for natural gas development

   a. Establish an oil and gas development policy that natural gas resources for use after 20-30 years must be discovered from now. To this end, promote early commercialisation of the already discovered resources and proactively invite exploration activities.

   b. Establish a global climate policy to construct modern energy infrastructure utilising clean natural gas first, and endeavour to decarbonise it in future.

2） Grand design of natural gas utilisation and demand outlook:

   a. Collect additional information on potential energy demand in regions not yet covered.

   b. Identify demand for natural gas, namely, demand in dense-demand areas suitable for gas grid development and other isolated large users for direct gas delivery. Also consider demand development timeline. The rest in sparce demand area may be supplied with LPG.

   c. Consider new demand such as NGVs and rural electrification. However, the mobility policy must be decided with careful consideration on the global trend toward promotion of electric vehicles.

   d. Compile the grand design for utilisation of natural gas and LPG and subsequent demand outlook. Feedgas demand for gas industry development such as fertiliser and large-scale LNG may be considered separately.

3） Grand design on natural gas supply system:

   a. Identify possibility and timing of new pipelines to Dodoma and Mombasa coherent with the PSMP 2020, any pre-concept for PSMP 2025 Update, and the agreement with Kenya. These may become the backbone of the national gas supply system.

   b. Consider interim and permanent roles of gas transport methods, namely, pipeline, CNG and LNG in view of the cost, timeline and supply security. Presumably, CNG may be adopted as an interim measure to create natural gas demand in the early stage, bridging to the permanent system with combination of the backbone pipeline, CNG and mini-LNG.

   c. Compile the grand design of the gas supply system with timeline of the system development.

To this end, the Study Team would like to recommend conduct of Framework Study, by which Tanzania will set out the grand design for the national gas supply system. There are several challenging issues. Gas demand presently expected at the time of project start-up is small and the gas supply system has to be constructed from the scratch. Deliberate preparation is necessary to create a viable project with regard to:

a. Comprehensive policy for gasification including support plans for gas users
b. Practicable project plan with creation of additional firm demand
c. Proper laws, regulations and codes, and inspection and licensing procedures
d. Fund raising plan for the upfront investment
e. Capacity development

Among others, creation of effective demand at project start-up is the most critical issue to formulate a viable, that is, *bankable project plan*.

Once the business is launched and reaches certain stable operation level successfully, the gasification plan will start rolling autonomously. Funds for further expansion will be recovered from the proceeds of gas sale. Engineers will be brought up and networks of gas service stations and auto repair shops will be developed further in a self-sustained manner. Thus, gas industry is expected to bring about robust benefits for the country. Despite the challenges to initiate the project, the Study team looks forward to proactive action by the Government of Tanzania for implementation of the Domestic Natural Gas Promotion Plan (DNGPP).