No.

THE UNITED REPUBLIC OF TANZANIA

FEASIBILITY STUDY ON SMALL-SCALE HYDROELECTRIC POWER DEVELOPMENT PROJECT IN KILIMANJARO REGION

JANUARY 1989

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

THE UNITED REPUBLIC OF TANZANIA

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PREFACE

In response to a request from the Government of the United Republic of Tanzania, the Japanese Government decided to conduct a feasibility study on the Small-Scale Hydroelectric Power Development Project in the Kilimanjaro Region and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Tanzania a study team headed by Mr. Hideo Sato, Director of the Civil Engineering Department, EPDC International Ltd., from August 1987 to December 1988.

The team held discussions on the Project with the officials concerned to the Government of Tanzania and conducted field surveys in the Kilimanjaro Region. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the development of the Project and to the promotion of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Tanzania for their close cooperation extended to the team.

Janaury 1989

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Mr. Kensuke Yanagiya, President
Japan International Cooperation Agency

Sir:

Submitted herewith is the Feasibility Report on the Small-Scale Hydroelectric Power Development Project in the Kilimanjaro Region of The United Republic of Tanzania. This Report was prepared by an EPDC International Co., Ltd. Study Team under commission from your Agency.

The Study Team, with the cooperation of the Tanzania Electric Supply Company, Ltd. (TANESCO), carried out field investigations from August 1987 to March 1988 and then prepared this report in Japan during the period from April to December 1988.

The process by which two among nine potential sites were selected, and the feasibility studies on the two sites selected, are covered in the main report. The data collected in the investigations, and the data used in the basic studies, are compiled in a separate volume.

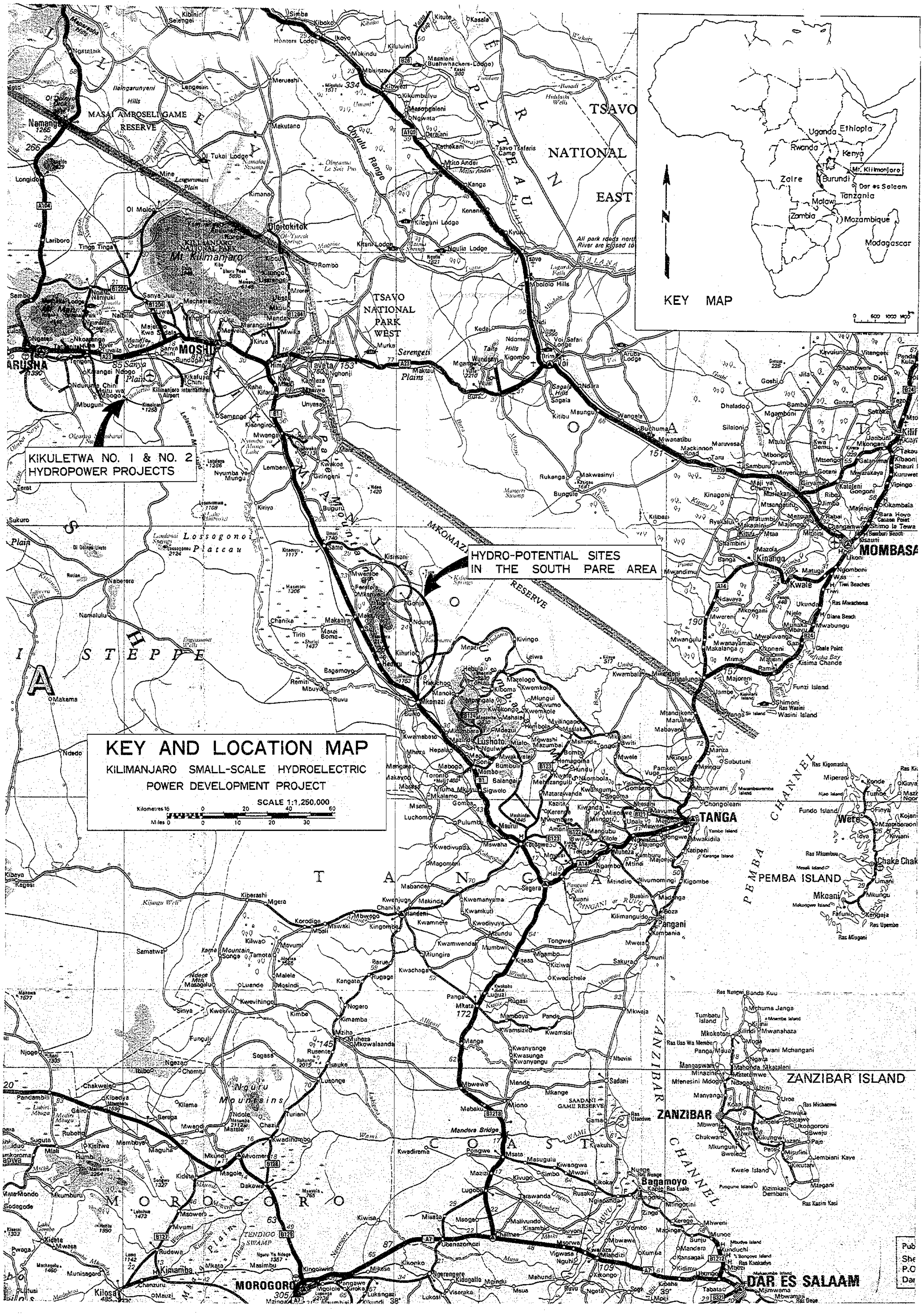
We sincerely hope that this Feasibility Report will serve to push forward the improvement and strengthening of the electric power supply capability of the Kilimanjaro Region, and thereby lead to the promotion of electric power development in Tanzania.

In submitting this Report, the Team wishes to express our sincere gratitude to all those who generously cooperated in carrying out the survey.

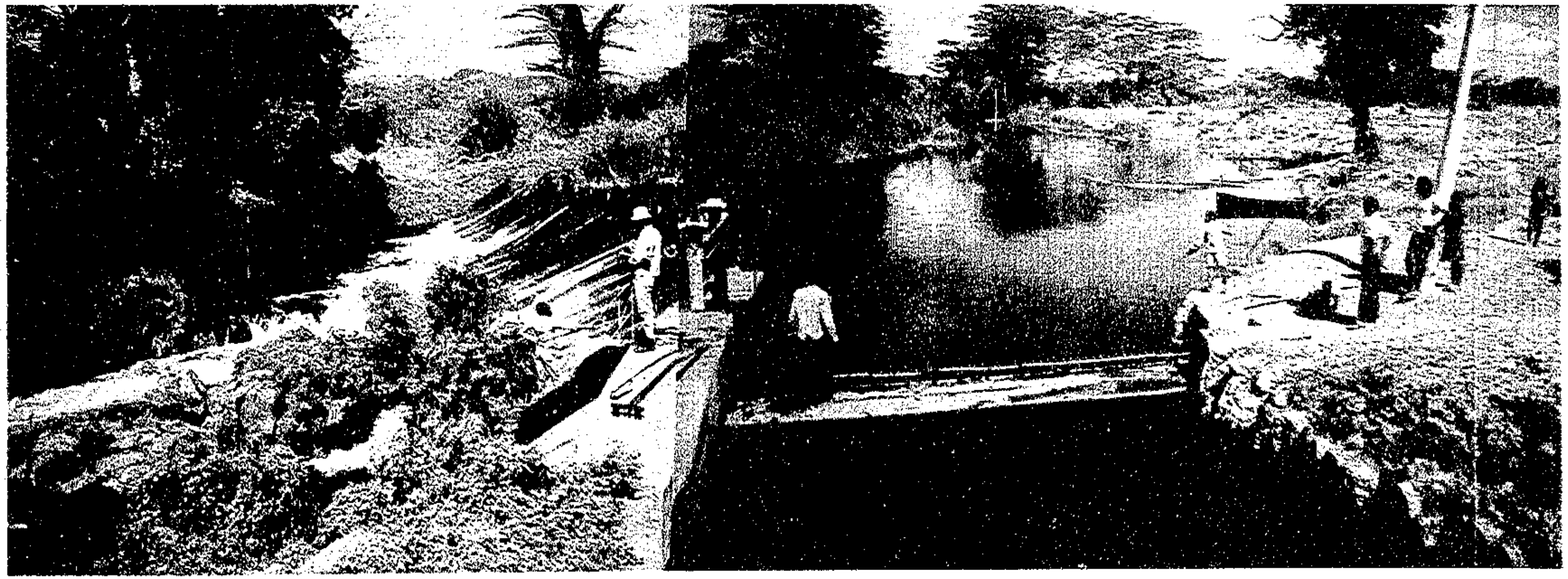
January 1989

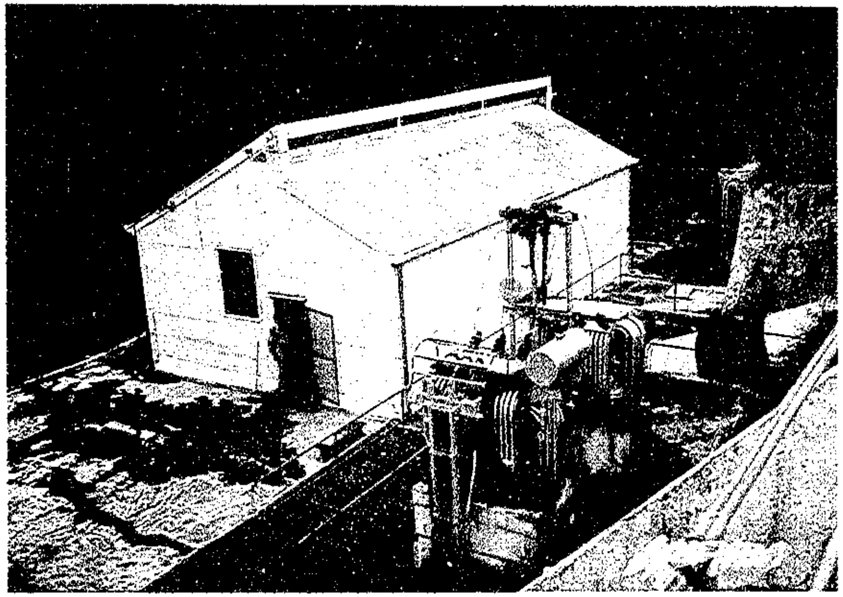
Respectfully,

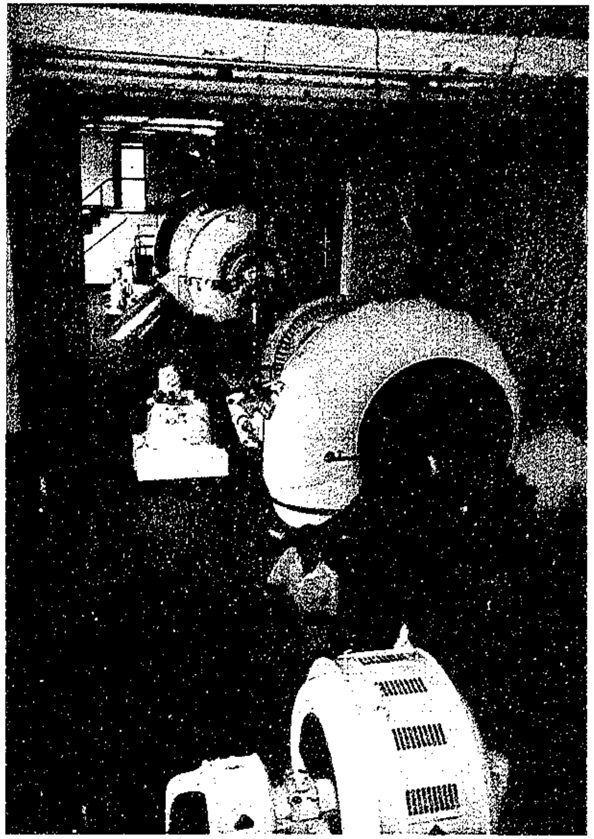
Hideo Sato
Team Leader
Small-Scale Hydroelectric
Power Development Project in
Kilimanjaro Region Study Team


KEY AND LOCATION MAP
KILIMANJARO SMALL-SCALE HYDROELECTRIC
POWER DEVELOPMENT PROJECT
SCALE 1:1,250,000
KIKULETWA NO. 1 & NO. 2
HYDROPOWER PROJECTS
HYDRO-POTENTIAL SITES
IN THE SOUTH PARE AREA
KEY MAP
TSAVO NATIONAL PARK EAST
TSAVO NATIONAL PARK WEST
MASAI AMBOSELI GAME RESERVE
Mt Kilimanjaro
MOSHI
ARUSHA
MOMBASA
TANGA
PEMBA ISLAND
PEMBA CHANNEL
ZANZIBAR ISLAND
ZANZIBAR CHANNEL
ZANZIBAR
DAR ES SALAAM
MOROGORO
Bagamoyo
Pangani
MKOMAZI GAME RESERVE
Lushoto

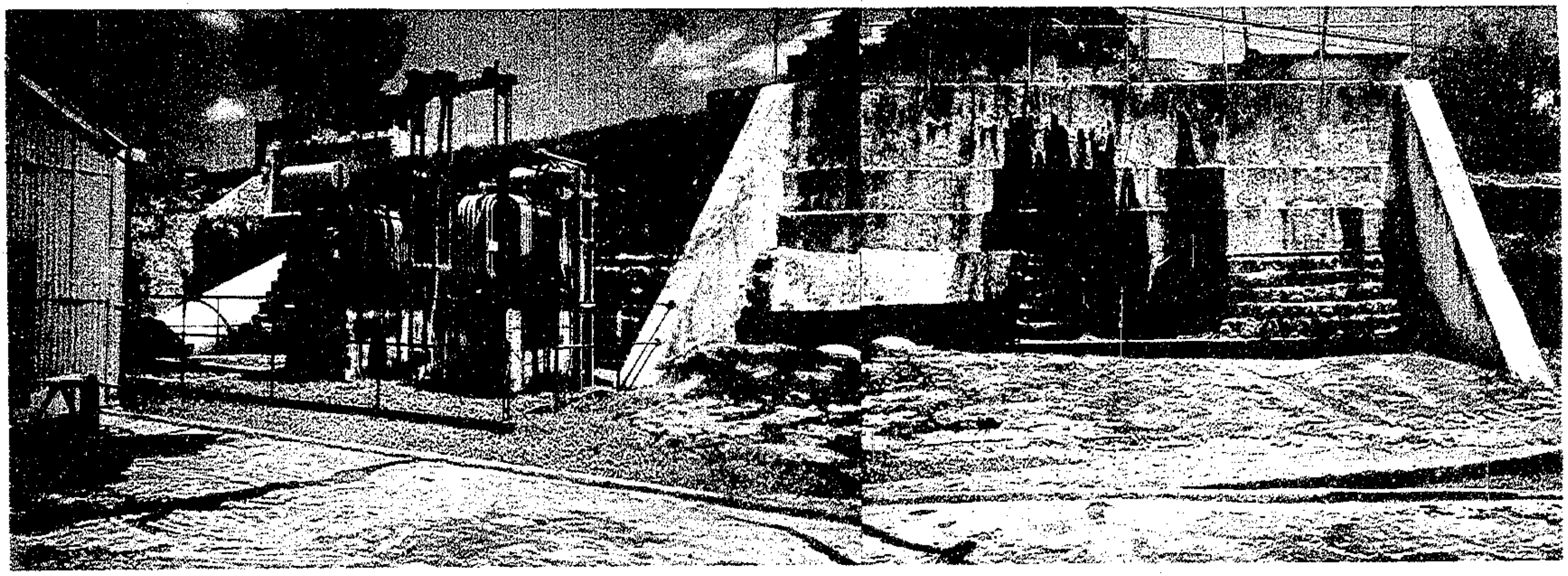
DIVERSION WEIR OF THE EXISTING TANESCO POWER STATION ON KIKULETWA RIVER



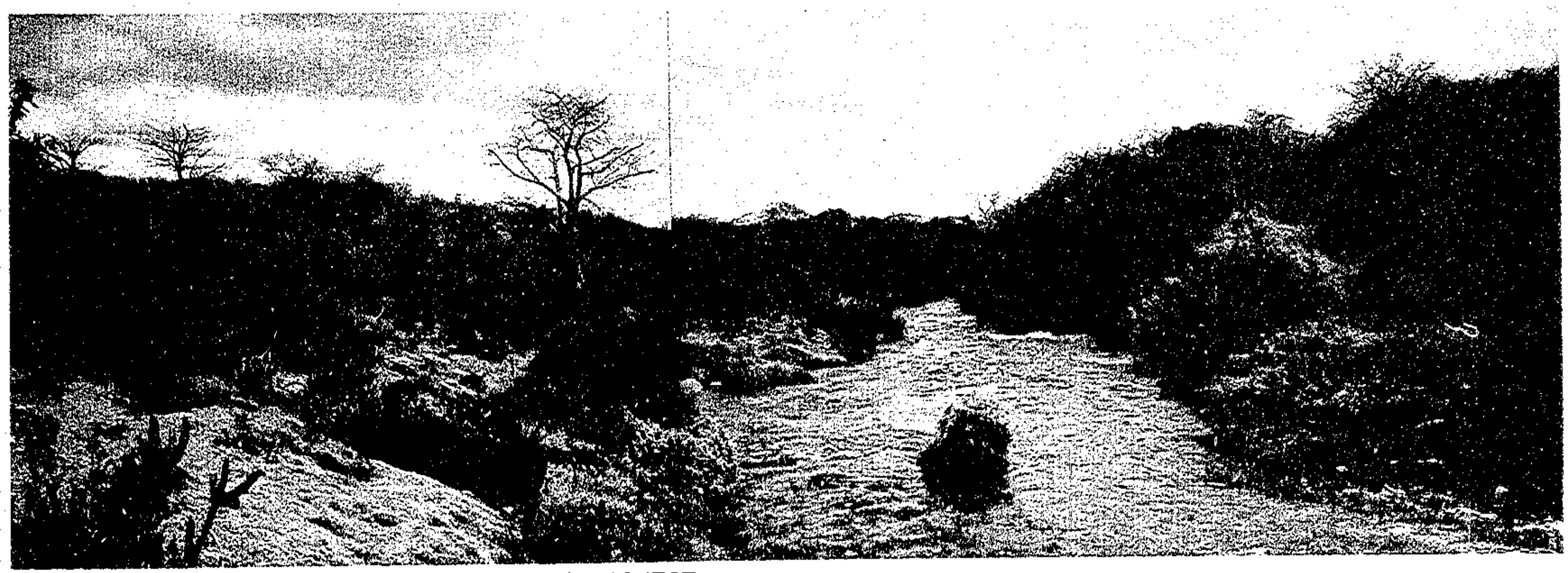




BUILDING AND ELECTRICAL EQUIPMENT
OF THE EXISTING TANESCO POWER STATION



TRANSFORMER AND HEAD TANK OF THE EXISTING TANESCO POWER STATION



PROPOSED INTAKE SITE FOR KIKULETWA NO. 2 PROJECT

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CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

(1) The Study for a Small-scale Hydroelectric Power Development Project in the Kilimanjaro Region was carried out in the following stages:

- Identification Stage:	Aug. 1987 - Dec. 1987
- Field Investigation Stage:	Jan. 1988 - Mar. 1988
- Preliminary Design Stage:	Apr. 1988 - Dec. 1988

At the Identification Stage, nine potential sites previously selected by Tanzania Electric Supply Company, Ltd. (TANESCO) were investigated and the priorities for development were studied.

Based on these studies, and following discussions between TANESCO and JICA, two potential sites, Kikuletwa No. 1 and No. 2, were selected from among the nine, and it was then decided to proceed to the field investigation stage. The reasons that these two sites were selected were as follows:

- The runoff of the Kikuletwa River is stable throughout the year, which is an extremely advantageous condition for a hydroelectric power development project.

- Cost-benefit evaluation of the nine sites indicated Kikuletwa No. 1 Project to be the most favorable followed by the Kikuletwa No. 2 project.

- From the viewpoint of the present state of power supply in the Kilimanjaro Region, it is more desirable to implement a large scale hydropower project close to the load center of Moshi and Arusha.

The potential sites Kikuletwa No. 1 and No. 2 are thus the most economically advantageous of the nine sites studied, and it is possible to plan the largest generating capacities for them. Site development would very greatly contribute to strengthening and improving the Kilimanjaro electric power system.

At the preliminary design stage, detailed investigations and studies were made of the Kikuletwa No. 1 (Rehabilitation) and No. 2 hydroelectric power development projects, and a feasibility study was carried out.

(2) The electric power produced at the Kikuletwa No. 1 Hydroelectric Power Development Project (Rehabilitation) and the Kikuletwa No. 2 Hydroelectric Power Development Project would be supplied to the Arusha-Kilimanjaro power system and would improve the electric power demand and supply situations of Arusha, Moshi, and their vicinities, which are connected to the system.

The load forecasts for the service areas of the Kilimanjaro Region for the years 1986, 1995, 2000, and 2005 are as follows:

	Peak Load (MW)	Electric Energy (GWh)
1986*	26.7	107.08
1995	44.3	168.05
2000	55.6	206.03
2005	69.7	253.04

* Actual

(3) The power supply in Arusha-Kilimanjaro region at present relies upon a total capacity of 11.9 MW consisting of Nyumba ya Mungu and the existing Kikuletwa and Arusha power stations. However, the maximum power demand in 1987 was 27.0 MW, and the shortage was made up mainly by supply from the Kidatu power station. This power had to pass through more than 700 km of the transmission lines so that there was a very large power loss, and a voltage drop in the region.

It is consequently recommended that Kikuletwa No. 1 and No. 2 hydroelectric power projects be implemented as soon as practicable in order to reinforce the supply capability and to mitigate the power shortage in Arusha-Kilimanjaro region.

If, in order to expedite implementation of these projects, the times required for detailed designing, financing, and construction are kept to their practical minimum, it will be possible to commence commissioning of Kikuletwa No. 1 and No. 2 Projects in 1991 and 1994, respectively.

(4) Comparison study of alternative plans indicates that the optimum development capacity of the Kikuletwa No. 1 Hydroelectric Power Development Project (Rehabilitation) will be 1,500 kW.

Of the principal structures, the existing intake, waterway, head tank, and other structures are to be used as much as possible by executing repair and improvement work.

Adjacent to the existing powerhouse, a new above-ground powerhouse is to be constructed, to be served by a penstock (diameter 2.50 m, length 20 m) and having an S-type tubular turbine (1,500 kW x 1 unit). The existing power plant (1,160 kW, presently operating at 560 kW) is to be retired after completion of the improvement work.

(5) Comparison study indicates that the optimum installed capacity of the Kikuletwa No. 2 Hydroelectric Power Development Project will be 11,000 kW.

The principal structures will be an intake dam (height 13.00 m), a regulating pond (storage capacity 118,000 m^3), headrace (culvert 2,250 m, open canal 1,050 m), head tank, penstock (1 line, inside diameter 2.6 m, length 835 m), Francis turbines (5,800 kVA x 2 units), and an above-ground powerhouse accommodating the turbines. The intake dam is to be constructed 2.2 km downstream of the existing TANESCO power station, and the powerhouse approximately 4 km further downstream.

(6) The geology and bedrock at the Kikuletwa No. 1 and No. 2 hydroelectric power development sites are sound and have ample bearing capacity for all major structures.

(7) The total construction costs for the Kikuletwa No. 1 (Rehabilitation) and Kikuletwa No. 2 hydroelectric power development projects are estimated as follows:

Total Construction Cost

Unit: US$$10^3$

	Local Currency	Foreign Currency	Total
Kukuletwa No. 1 (Rehabilitation)	681	6,217	7,198
Kikuletwa No. 2	7,497	41,903	49,400

(8) The results of the economic evaluation of the Kikuletwa No. 1 (Rehabilitation) and Kikuletwa No. 2 hydroelectric power development projects are as given below. The benefit of these hydroelectric power stations was considered to be the cost of alternative diesel generating plants of capacities equivalent to the stations.

(i) Kikuletwa No. 1 Hydropower Station (Rehabilitation)

Benefit-cost ratio (B/C)	1.27
Surplus benefit (B - C) US$$10^6$	1.632
EIRR (%)	13.3

(ii) Kikuletwa No. 2 Hydropower Station

Benefit-cost ratio (B/C)	1.17
Surplus benefit (B - C) US$$10^6$	6.492
EIRR (%)	12.0

Both Kikuletwa No. 1 (Rehabilitation) and Kikuletwa No. 2 hydroelectric power development projects have benefit-cost ratios (B/C) and surplus benefits (B - C) that are advantageous when compared with an alternative diesel plant.

The EIRR exceeds the social discount rate of 10 percent normally used for evaluating projects in Tanzania, indicating that these projects are economically feasible.

(9) The sources of funds required for construction of the projects, and the terms of borrowing, were assumed as follows:

	Annual Interest Rate	Repayment Term
- Soft loan on government-to-government basis	1.5%	30 yr (including grace period of 10 yr)
- Project loan from international financing institution	7.64%	15 yr (including grace period of 5 yr)

The source of income from the project was considered to be the sales of power, with 67 percent of the estimated 1988 unit price (US cent 11.87/kWh), or US cent 7.95/kWh, assumed to be created by the power generating sector.

The financial internal rates of return (FIRR) obtained by calculating revenues and expenditures and cash flow for 30 years following start-up are as follows:

Kikuletwa No. 1 Project: 6.1%

Kikuletwa No. 2 Project: 5.9%

Based on the assummed electricity rate, the FIRR of the two projects indicate that they are financially sound.

(10) The Kiyungi substation at Moshi, and the Njiro substation at Arusha, are at the terminal end of a 132-kV interconnected system and are far from major power generation sites (more than 700 km from Kidatu Power Station). The voltage drop in the Arusha-Kilimanjaro Region is, therefore, great.

The results of power system analysis for this region are as follows:

System Condition	Demand (MW)	Bus Voltage of S.S. (%) Kiyungi 132 kV	Kiyungi 33 kV	Njiro 132 kV	Transmission Loss (MW) betw. Chalinze and Njiro S.S
Present state (1987)	27.0	85.0	100	83.4	-
1991					
Kikuletwa No. 1					
bef. rehabilitation	36.9	81.1	88.3	69.8	9.95
aft. rehabilitation	36.9	94.3	103.5	82.3	7.41
1994					
Kikuletwa No. 2					
bef. start-up	42.3	78.7	86	62.5	14.07
aft. start-up	42.3	93.2	101.0	88.7	4.87

As shown above, the bus voltages of the substations of Kiyungi and Njiro are expected to drop even further as power demand increases in the region.

Unless rehabilitation of Kikuletwa No. 1 Power Station is carried out in 1991, the bus voltage drop will be quite large (as shown above), it will become difficult to operate the electric power system, and it will be necessary to perform load shedding or to take other measures to maintain the system voltage.

A similar voltage problem will occur, if the Kikuletwa No. 2 Hydroelectric Power Station is not commissioned in 1994.

The redevelopment scheme for Pangani Falls Power Station (from 17.5 MW to 60 MW), presently being planned by TANESCO is located at a distance of approximately 300 km from the Arusha-Kilimanjaro Region. Therefore, even if this redevelopment is completed by 1993, it would still be difficult, from the standpoint of system composition, to receive reactive power for maintaining the system voltage.

Based on the above considerations, the time for the commissioning the two power stations should be 1991 for the Kikuletwa No. 1 hydroelectric power station rehabilitation project (1,500 kW), and 1994 for the Kikuletwa No. 2 hydroelectric power station project (11,000 kW).

(11) The pertinent features of No. 1 and No. 2 projects are as follows:

MAIN FEATURES OF KIKULETWEA NO. 1 AND KIKULETWA NO. 2 HYDROPOWER PROJECTS

	Kikuletwa No.1 Project		Kikuletwa No.2 Project	
1. Catchment Area	2,200 sq.km		2,280 sq.km	
2. Diversion Facility	Kikuletwa	Kware		
Type	Concrete	Concrete	Concrete and Fill type	
Height	3.0 m	2.5 m	13.0 m	
Crest length	15.0 m	15.0 m	103.5 m	
3. Regulating Reservoir				
High Water Surface	-		820 m	
Gross Storage	-		209,000 cu.m	
Effective Storage	-		118,000 cu.m	
Draw down	-		2 m	
4. Conduction Canal	Kikuletwa	Kware	Open Canal	Culvert
Length	370 m	1,676.5 m	1,050 m	2,215 m
Type	Rectangular Open Canal	Rectangular Open Canal	Trapezoidal Canal	Semi-circular in upper part & Rectangular in lower part
Bottom Width	3.8 m	3.8 m	3.0 m	3.0 m
Height	3.3 m	3.3 m	2.3 m	3.8 m
5. Power Generation Plan				
Intake Level	830.47 m		817.00 m	
Tailrace level	817.40 m		730.90 m	
Effective Head	12.70 m		78.20 m	
Power Discharge				
Maximum	15.40 cu.m/sec		17.90 cu.m/sec	
Firm	10.53 cu.m/sec		17.90 cu.m/sec (for firm peak)	
Annual Energy Production	10.53×10^6 kWH		67.09×10^6 kWh	
6. Transmisison Line	(Existing)		(New)	
Length	15 km		14 km	
Voltage	33 kV		33 kV	
7. Construction Cost	7.2×10^6 US$		49.40×10^6 US$	
8. Construction Cost per kWh	68.4 US cent		73.6 US cent	
9. Benefit-Cost Ratio	1.27		1.17	
10. Economic Internal Rate of Return	13.3%		12.0%	
11. Financial Internal Rate of Return	6.1%		5.9%	

2. RECOMMENDATIONS

Based on the conclusions described above, the following recommendations are made.

(1) In view of the present state of power demand and supply capability in the Arusha-Kilimanjaro Region, Kikuletwa No. 1 and No. 2 Hydrocelectric Power Development Projects should be completed as soon as practicable.

(2) The Kikuletwa No. 1 Hydroelectric Power Development Project (Rehabilitation) and the Kikuletwa No. 2 Hydroelectric Power Development Project are extremely feasible from both engineering and economic standpoints. Construction of Kikuletwa No. 1 Hydroelectric Power Development Project (Rehabilitation) should be started in 1990 so that it can be completed same in 1991. For this reason, a definite design and preparation of bid documents should be commenced immediately.

(3) The desirable completion time for the Kikuletwa No. 2 Hydroelectric Power Development Project is 1994. To reach this target, construction work should commence in 1991, so that necessary preparations should be completed within a short period of time.

CHAPTER 1
INTRODUCTION

CHAPTER 1 INTRODUCTION

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CHAPTER 1 INTRODUCTION

1.1 OUTLINE OF PROJECT AREA

1.1.1 Geographical Location

The United Republic of Tanzania is located in the eastern part of Africa, immediately south of the equator. The country extends from 1°00' to 11°44' south latitude, and from 29°40' to 40°27' east longitude. Tanzania is bounded by Kenya and Uganda to the north, Rwanda, Burundi, Malawi, Zaire, and Zambia to the west, Mozambique to the south, and fronts on the Indian Ocean to the east. The area of the national territory is 945,000 sq.km.

The land consists of the Indian Ocean Coastal Region centered at Dar es Salaam, the Lake Victoria Basin Region at the northwestern part centered at Mwanza, and the Kilimanjaro Region at the northeastern part centered at Arusha and Moshi.

The project area is located in the Kilimanjaro Region, spread along the southwest to southeast skirt of the 5,895m high, permanently snowcapped Mt. Kilimanjaro.

The nine (9) hydro-potential sites in the Kilimanjaro Region which were proposed by Tanzania Electric Supply Company Ltd. (hereinafter, TANESCO) are located the south slope of Mt. Kilimanjaro or on the steep east slope of Mt. South Pare.

Kiluletwa No. 1 and No. 2 Hydropower projects, which were among the nine sites, are to be constructed on the Kiluletwa River, which runs eastward at the south foot of Mt. Kilimanjaro.

After merging at the Nyumba ya Mungu Reservoir with the Ruvu River which flows on the east slope of Mt. Kilimanjaro, the river is called the Pangani River. The Pangani River empties into the Indian Ocean.

1.1.2 Climate

The climate of the Kilimanjaro Region varies with the geographical conditions and altitude. Temperatures are much cooler than in the coastal region, and drop further as altitude increases. The mean temperatures at Moshi are as follows:

(Unit: Celsius)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Max.	33.2	33.5	32.0	29.5	26.7	25.9	25.7	26.5	28.8	30.8	31.9	31.9
Min.	17.4	17.9	18.6	19.1	18.2	16.7	15.6	15.8	15.3	16.6	17.5	17.4

The Kilimanjaro Region, unlike other parts of Africa belonging to semi-arid zones, is blessed with rainfall. Precipitation at the mountainside of Kilimanjaro is 1,500 to 2,000 mm/yr; at the mountainside of Pare 800 to 1,300 mm/yr; in the plains area, 400 to 600 mm/yr.

1.1.3 Population

The population of the United Republic of Tanzania was estimated to be 22.46 million as of 1986. The population growth rate in recent years has been 3.3 percent. According to "Tanzania in Figures, 1986", the population density is 23.8 per sq.km.

The population of the Kilimanjaro Region is 1.24 million, or about 5 percent of the country's entire population. Of this number, the population of Moshi is 452 thousand. The population is concentrated at the middle to higher parts of Mt. Kilimanjaro and Mt. Pare, between elevations 800 to 2,000 m, where temperatures are pleasant.

This region has a high population density, second in the country after Dar es Salaam. The population is concentrated at the higher elevations, where agriculture is practised. The population at the lower elevations is more dispersed.

1.1.4 Economy

The center of Tanzania's economy is Dar es Salaam, in which the greater part of the non-agricultural and non-forestry activities -- such as commerce, manufacturing and politics -- is concentrated.

Agriculture is Tanzania's main economic activity. Agricultural production in 1984 constituted 54 percent of the gross domestic product, and agricultural products comprised 75 to 80 percent of total exports. The principal agricultural products are coffee, cotton, sisal, cashew nut, tobacco, tea, pyrethrum, and clove.

Tanzania's most important economic objectives are to increase agricultural production and to achieve self-sufficiency in food. Production, however, has levelled off, and self-sufficiency in food has not yet been attained.

In recent years, industries such as oil refining, cement manufacturing, and fertilizer manufacturing have developed. The proportion of manufacturing in the gross domestic product of 1984 was 8 percent.

Since 1981, however, manufacturing production has continuously declined, with particular reduction in manufacturing based on imported raw materials. Because of a shortage of foreign exchange, imported raw materials, equipment and parts are lacking. Frequent power outages and water supply failures have greatly affected the output of small- to medium-scale industries as well as of a number of large-scale industries including cement, textiles (Friendship Textile), and aluminium (ALAF).

The government suspended the Fourth Economic Development Five-Year Plan, which had been scheduled for implementation from 1981 through 1985, and since 1981 has established a National Economic Salvation Program (NESP) and structural adjustment programs aimed at rebuilding the economy.

These structural adjustment programs target an annual GDP growth rate of 4.5 percent. The main items are as listed below.

(i) Agricultural production: increase in production of food crops and export-oriented crops.

(ii) Earning of foreign exchange through exports and saving of foreign currency through utilization of domestic products.

(iii) Repair of the infrastructure: transportation, communication, and energy.

(iv) Rehabilitation of the production capacities of existing agricultural and manufacturing industries.

(v) Reduction of the national deficit, limitation of the money supply, and suppression of inflation.

At least 80 percent of the funds required for these programs will depend on monetary aid from foreign countries. The Tanzanian economy has improved slightly in the last several years through steps taken in line with IMF recommendations. But there still remain fundamental problems, including chronic foreign exchange shortages, increased foreign debt, and high financial deficits.

1.1.5 Energy Resources

(a) Coal

Reserves of coal are estimated to be more than 1 billion tons. The coal is said to contain 13 to 40 percent ash and to have very low sulfur content.

At present, coal-field development on a scale of 500,000 tons annually is being implemented by STAMICO.

(b) Natural Gas

Exploratory drilling for gas and oil has been active since 1977, when a gas field with 19.3 billion m3 in potential reserves was discovered at Songo. In July 1982, a large-scale gas field was discovered offshore of Kimbiji, 40 km south of Dar es Salaam, and a feasibility study has been commenced.

(c) Geothermal Energy

Although there seems some possibility for implementing geothermal energy, practical development plans have not yet been studied.

(d) Hydropower Potential

The hydropower potential of Tanzania is estimated at 38 million kW, with annual energy production of approximately 190 billion kWh. At present, only 250,000 kW has been developed, or only 0.65 percent of the whole. Hydropower is, therefore, a very important energy resource for the future.

1.2 BACKGROUND OF PROJECT

Generation, transmission, transformation, and distribution of electric power for all of Tanzania is carried out by Tanzania Electric Supply Company, Ltd. (TANESCO), all of whose capital comes from the Government.

TANESCO owns generating facilities of 398.34 MW (rated capacity: 371.82 MW) of which 253.22 MW (64 percent) is hydro and 145.12 MW (36 percent) is thermal.

TANESCO's power system comprises both an interconnected system and isolated systems. Power for the interconnected system is supplied mainly by hydro power stations, with thermal power stations (diesel generating stations) functioning merely to supply reserve capacity.

The main portion of the electric power for the Kilimanjaro Region is supplied via long-distance transmission lines from major power stations such as Kidatu Hydro Power Station (200 MW). Specifically, power is supplied through a 132-kV transmission line, called the Coastal Line, which runs approximately 600 km between the Chalinze Substation in Dar es Salaam and the Njiro Substation in Arusha, via Hale, Same, and Moshi. The Kilimanjaro region is situated at the very end of the interconnected power system, so that power supply to the region frequently suffers voltage fluctuations and transmission line faults. In other words, the power supply is not stable.

In addition, power demand has increased at an accelerated pace, following the 1984 completion of a power transmission and distribution network for part of the Kilimanjaro Region, achieved with technical cooperation from Japan.

In order to secure a stable power supply to meet the increasing demand, it has become necessary to reinforce power supply sources within the region, close to the load centers.

It was from this point of view that TANESCO considered development of hydropower projects which would utilize the excellent water resources and topography of the Kilimanjaro Region.

In January 1987, therefore, the Tanzanian Government and TANESCO requested from the Japanese Government, which had already extended cooperation in the comprehensive development project and a power transmission and distribution project in the Kilimanjaro Region, for technical cooperation in a "Kilimanjaro Small-scale Hydroelectric Power Development Project."

Based on this request, the Japanese Government dispatched a preliminary survey team from the Japan International Cooperation Agency (JICA) in March of 1987, and a preliminary field investigation was carried out in the Kilimanjaro Region. At the same time, discussions were held with TANESCO, the executing agency responsible for this Project, regarding the scope of the work to be considered. On March 23rd 1987, both parties agreed on the "Scope of Work for the Feasibility Study on Small-scale Hydroelectric Power Development Project in Kilimanjaro Region, Tanzania" (S/W).

1.3 OBJECTIVES AND SCOPE OF WORK

The principal objectives and the scope of work in this survey are summarized as follows:

(i) Identification Stage (August - December 1987)
Selection of high priority sites from among the nine (9) potential sites proposed by TANESCO.

(ii) Field Investigation Stage (January - March 1988)
Guidance for TANESCO's preparation of topographic maps of the selected potential sites, and in carrying out aerial photography, mapping, and geological investigations. Detailed reconnaissance for the feasibility study.

(iii) Preliminary Design Stage (April - December 1988)
Study of the optimum development scale and development scheme for the selected sites, from the economic and technological viewpoints, and preparation of a feasibility study report.

1.4 STUDY AT RESPECTIVE STAGES

(1) Identification Stage

Field investigations were conducted from August 12 to October 31, 1987, following which analyses and studies were carried out in Japan through the middle of December. The principal items of work performed in this stage were as follows:

- Investigation of the present state of power supply in the Kilimanjaro Region, and problems such as voltage drop
- A load forecast, through the year 2005, for the region
- Field investigation of the nine potential sites located on five rivers, and review of development plans for the individual sites
- Preliminary hydrological study
- Guidance to TANESCO in conducting levelling surveys, from intake to power station sites, which were done to supplement the existing topographic maps
- Beneift-cost analysis of the potential sites by the selection of which sites to carry into the Field Investigation Stage
- Preparation and submittal of an interim report covering the investigations and studies conducted during this Identification Stage

At the discussions held between JICA and TANESCO on December 18, 1987, which were based on the Interim Report, two sites - Kikuletwa No. 1 (rehabilitation project) and the Kikuletwa No. 2 were chosen to be carried into the Investigation Stage. These sites had been accorded high priority based on comparative benefit-cost anaylsis and on the potentially sizable development scale.

(2) Field Investigation Stage

The Field Investigation Stage was carried out from January 7 to March 21, 1988. Field investigation of the Kikuletwa No. 1 and No. 2 sites, selected following the previous stage, was conducted, and the feasibility study was advanced. The work of this stage was as follows:

- Guidance for TANESCO's installation of control points and execution of ground surveys prior to aerial photography of the project area

- Taking of 1/20,000-scale aerial photographs required for preparation of (1/5,000) topographic maps of the approximately 300 sq. km project area

- Taking of 1/8,000-scale aerial photographs required for preparation of 1/1,000 longitudinal and transverse profiles

- Preparation of 1/5,000 topographic maps and 1/1,000 longitudinal and transverse profiles

- Guidance for TANESCO's ground surveying and preparation of 1/500 topographic maps for the main structural sites for Kikuletwa No. 1 and No. 2

- Performance of approximately 200 m of core boring, and geological observations of cores

- Material investigations including aggregates

- Field investigations of environment, runoff, and access

- Guidance in installating the automatic water level recorder furnished by JICA, and observation and recording

(3) Preliminary Design Stage

Preliminary design work for the Kikuletwa No. 1 and No. 2 sites was performed in Japan on the basis of the results of the field investigations and other studies conducted in the previous stages.

- Determination of optimum development scheme
- Preliminary design

  (a) Principal civil structures such as intake dam, intake facilities, water conveyance canals, head tank, penstock, powerhouse, tailrace structure, etc.

  (b) Steel structures such as gates and penstock pipes

  (c) Generating and transforming equipment such as turbines, generators, etc.

  (d) Transmission line

  (e) Diversion work during construction

  (f) Site selection and general layout of temporary facilities for construction

- Cost estimation by work item, and breakdown of foreign and local currency requirements

- Preparation of work schedule starting from the detailed design stage and ending with commercial operation

- Economic and financial analyses

  (a) Economic analyses and sensitivity analyses by benefit-cost method and EIRR method

  (b) Financial analyses and sensitivity analyses by FIRR method

- Environmental impact assessment

- System stability analysis of Kilimanjaro power transmission and distribution network, considering the results of the connection of proposed small-scale hydro-power stations to the Kilimanjaro power transmission and distribution network systems

- Training of TANESCO counterparts (Nov. - Dec., 1987)

  Mr. David E. P. Ngula
  Senior Hydrologist
  Project and Transmission

  Mr. Joseph K. Tesha (Aug. - Oct., 1988)
  Director
  Project and Transmission

1.5 MEMBERS OF JICA TEAM

The members of the team that participated in the Feasibility Study, and their assignments, are as follows:

EPDC International Ltd.

Hideo SATO	:	Team Leader & hydropower planning
Shigehisa WADA	:	Design of civil structures
Toshihiko MITSUDA	:	Hydropower planning and cost estimate
Ken NIIMI	:	Geological survey & study
Akiyoshi NODA	:	Hydrological study & environmental assessment
Yukiteru TAKEYA	:	Power development planning
Susumu OHTSUKA	:	Design of electrical work
Tosaku OKABAYASHI	:	Power system engineering
Tetsuro KOBAYASHI	:	Economic & financial study

KAIHATSU DOBOKU Consulting Engineers Co., Ltd.

Mitsuru SHIGETA	:	Boring engineering

PASCO International Inc.

Seiji YOSHII	:	Survey engineering
Yasuyuki KUWAHATA	:	Survey engineering
Kiyoto HAYAKAWA	:	Planning & supervising of aerial photography

CHAPTER 2
PRESENT STATE OF ELECTRIC UTILITIES AND NECESSITY OF DEVELOPMENT

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CHAPTER 2 PRESENT STATE OF ELECTRIC UTILITIES AND NECESSITY OF DEVELOPMENT

2.1 PRESENT STATE OF ELECTRIC UTILITIES IN TANZANIA

2.1.1 Electric Utility - TANESCO -

Generation, transmission, and distribution of electricity in Tanzania are undertaken by TANESCO (Tanzania Electric Supply Company, Ltd.), a wholly government-owned utility, pursuant to Article 13 of the Electricity Ordinance.

In addition, private companies in Tanzania who own generating facilities totalling approximately 20 MW.

TANESCO is administered under the Ministry of Energy and Minerals.

TANESCO's Board of Directors, which is its decision-making body, consists of nine (9) members, including the chairman.

The organization of TANESCO is shown in Fig. 2.1.1.

2.1.2 Generating Facilities

(1) General

The TANESCO power system comprises an interconnected grid system and isolated systems. The former serves major towns in the northeast, center, and southwest regions of the country; the isolated systems serve a number of load centers, but no large cities, which are scattered throughout the country.

(i) Interconnected Grid System

As of the end of 1987, TANESCO owned 398.34 MW of total installed capacity. Of this capacity, 334.87 MW supplied the grid system, and 63.47 MW supplied the isolated systems.

Mtera hydro power station, its installed capacity is 80MW (40MW, 20 Units) and average annual energy production is 303 GWh, No. 1 Unit and No. 2 Unit of which were commissioned in June and in December 1988 respectively.

The general features of the power stations owned by TANESCO are shown in Table 2.1.1.

The grid system, relies mainly on power supplied by hydropower plants; the hydropower plants have a total installed capacity of 253.2 MW, which is 76% of a total capability of the grid system. The remainder of the grid system's power is supplied by thermal power plants with a total installed capacity of 81.65 MW.

Of the hydropower stations, Kidatu (204 MW) and Mtera (80 MW), which are on the Great Ruaha river, and Nyumba Ya Mungu (8 MW), which is on the Pangani river, have reservoirs, and can be operated to supply the peak load of the grid system.

Two hydropower stations, Hale (21 MW) and Pangani Falls (17.5 MW), are located in the downstream of the Nyumba Ya Mungu reservoir.

The reservoirs of the Hale and Pangani Falls power stations are very small, and these two power stations rely greatly on the storage available at Nyumba Ya Mungu.

Maintenance of the existing power stations has been insufficient, partially due to a lack of spare parts. All the hydropower stations have been in need of rehabilitation. Actual conditions of power stations are as follows.

(a) Kidatu

Unit No. 1 developed a crack on the turbine cover. Replacement work was started in October 1987 and completed in February 1988. Rehabilitation was then started on Unit No. 2, and is scheduled for completion in September 1988.

(b) Hale

With the assistance of the Norwegian Agency for International Development (NORAD), rehabilitation of Hale power station was completed in May 1987.

(c) Nyumba Ya Mungu

Unit No. 1 was dismantled and sent to Norway for reconditioning. The work was completed and the unit was recommissioned in August 1988. Rehabilitation of Unit No. 2 is under way and is scheduled to be completed in March 1989.

(d) Pangani Falls

All the generating units now operating are in need of rehabilitation. A Pangani Falls redevelopment project, with an installed capacity of 60 MW, is presently under study. If this project is completed as scheduled in 1992, the existing Pangani Falls power station (17.5 MW) will be retired.

(e) Kikuletwa

Unit No. 1 (600 kW) has been out of service for 10 years. Unit No. 2 (400 kW) was rehabilitated in 1986 and is now operating at about 80% of rated capacity. Unit No. 3 (160 kW) is operating, but has deteriorated following years of service and is in need of rehabilitation.

(ii) Isolated Systems

A total installed capacity of 63.47 MW of small-scale diesel power stations presently supplies electricity to load centers scattered throughout the country. With the extension of the grid system to the northwest region, local towns of Shinyanga, Mwanza, Musoma and Tabora will be incorporated into the grid system within 1988 or 1989.

(2) Transmission Facilities

The transmission voltages are 220 kV and 132 kV. The distribution voltages are 33 kV and 11 kV. At present, 66 kV lines are used in some areas of Arusha and Moshi Regions. The outline of the power system is shown in Fig. 2.1.2.

The existing 220 kV lines connect Kidatu power station to Ubungo substation at Dar es Salaam in the east and to Iringa Mufindi and Mbeya in the southwest. Another 220 kV line extends northwest from Iringa to Mtera, Dodoma, and Singida.

Between Dodoma and Sinyanga, the 220 kV line is operated at 33 kV because of the small load.

The 132 kV transmission line extends from Morogoro to Chalinze and Ubungo, and further leads to substations in Hale, Tanga, Same, Kiyungi, and Njiro in the northeastern areas.

Electricity supply to Zanzibar is via a 132 kV overhead line from Ubungo to Ras Kiromoni and a 132 kV submarine cable from there to Zanzibar Island. These lines are owned by the State Fuel and Power Corporation, but TANESCO is responsible for the maintenance of the facilities on the mainland. Diesel power stations in Zanzibar are operated only for standby.

The extension of 220 kV transmission lines from Singida to Shinyanga and Mwanza in the northwestern area was completed in June 1988. Extension of 132 kV lines from Mwanza to Musoma and Shinyanga is under construction.

As of the end of 1987, transmission line routings and lengths, including lines under construction were as follows:

Voltage (kV)	Number of Circuit	Routing	Line length (km)
220	1	Kidatu - Morogoro - Ubungo	300
220	1	Kidatu - Iringa - Mufindi - Mbeya	506
220	1	Iringa - Dodoma - Singida	454
132	1	Ubungo - Chalinze - Morogoro	179
132	1	Chalinze - Hale - Same - Arusha	563
132	1	Hale - Tanga	60
132	1	Ubungo - Zanzibar	41
(Under construction)			
220	1	Singida - Shinyanga - Mwanza	360
132	1	Mwanza - Musoma	210
132	1	Shinyanga - Tabora	200

A one-line diagram of the grid system is shown in Fig. 2.1.3.

2.1.3 Power Market

(1) Energy Consumption

(i) General Situation

From 1973 to 1980, energy consumption in Tanzania grew at a rapid average yearly rate of 8.1% from 431.43 GWh to 745.58 GWh. Growth then turned sluggish, however, reflecting economic difficulties, and particularly the lack of foreign exchange. Energy consumption grew from 745.58 GWh in 1980 to 782.98 GWh in 1985, and to 909.11 GWh in 1986. This represents an average growth rate of only 1.0% per year for the period from 1980 to 1985, and 3.2% per year for the period from 1980 to 1986. In 1986 energy consumption, however, was 16.1% above that of the previous year, reflecting the beginning of a national economic recovery.

(ii) Energy Consumption by Category of Consumers

The electricity consumers are classified by tariff class into 6 categories: Domestic (Class 1), Commercial (Class 2), Light Industrial (Class 3), Commercial and Industrial - Low Voltage (Class 4), Commercial and Industrial - High Voltage (Class 5), and Public Lighting (Class 6).

In 1986, industrial use accounted for 60% of the total consumption, followed by domestic use, which accounted for 26%. Commercial consumption accounted for 10% of the total.

The 1973-to-1986 growth in energy consumption by consumer category is shown in Table 2.1.2 and may be summarized as follows:

Category	Share in 1986	Annual growth rate 1973-80	Annual growth rate 1980-86
Domestic	25.7%	11.3%	7.0%
Commercial **	9.3%	7.3%	-0.6%
Industrial **	60.0%	7.0%	2.1%
Public Lighting	0.4%	5.2%	-8.9%
Zanzibar	4.6%	-	2.1%
Total	100 %	8.1%	3.2%

(Note): "**" corrected to the 1970 to 1979 base tariff structure.

(iii) Energy Consumption by Region

As shown in Table 2.1.2, energy consumption in the interconnected system grew from 372.29 GWh in 1973 to 639.98 GWh in 1980, and to 822.28 GWh in 1986. Energy consumption in the isolated systems grew from 59.14 GWh in 1973 to 124.54 GWh in 1984, and then decreased to 87.39 GWh in 1985 and to 86.83 GWh in 1986. This decrease is due to interconnection of major towns of Iringa, Mbeya, Dodoma and Singida to the grid system in 1985 and 1986. Thus, the ratio of energy consumption in the interconnected system to the total consumption from the TANESCO power system increased from 85.8% in 1980 to 90.4% in 1986.

In 1986, the regional shares of energy consumption from the interconnected system were as follows:

Region	Energy consumption (GWh)	Share (%)
Arusha	64.03	7.8
Moshi	43.79	5.3
Tanga	85.88	10.4
Dar es Salaam	415.11	50.5
Zanzibar	41.59	5.1
Morogoro	65.69	8.0
Iringa	63.56	7.7
Dodoma	13.38	1.6
Singida	3.08	0.4
Mbeya	26.17	3.2
Total	822.28	100.0

(2) Energy Generation and Loss Factor

Table 2.1.3 shows yearly energy generation for the years 1973 to 1986. In 1986, the total energy generation of the complete power system was 1,146.16 GWh, of which 1,041.09 GWh (90.8%) was generated in the interconnected system and 105.07 GWh (9.2%) in the isolated systems.

In the interconnected system, the total installed capacity of hydropower stations (253.2 MW) was 76% of the total installed capacity (334.87 MW), while the energy generated by these hydropower stations was 99.3% of the total power generated. About 87% of total system's generation of 1,041.09 GWh was generated by Kidatu power station, as indicated below.

	Energy generation in 1986 (GWh)	
Hydro:		
Kidatu	900.93	
Pangani Falls	72.28	
Nyumba Ya Mungu	45.02	
Hale	14.18	
Kikuletwa	1.35	
Tosamaganga	0.02	
Subtotal	1,033.78	(99.3%)
Thermal:	7.31	(0.7%)
Total	1,041.09	(100 %)

From 1973 to 1979, the energy loss factor in the interconnected system varied between 13.8% and 18.0% with an average of about 16%. Losses, however, reached 20.6% in 1983, 21.7% in 1985, and 21.0% in 1986.

(3) Peak Load and Load Factor

(i) General Situation

The peak load trend for 1973 to 1986 is shown in Table 2.1.3. Coincident peak load in the interconnected system in 1986 was 183.1 MW. In the same year, the peak load in the isolated systems, assuming a diversity factor of 90%, was 25.3 MW.

From 1980 to 1986, the annual load factor in the interconnected system was almost constant, at about 65%. During the same period, the annual load factor in the isolated systems was 48.0%.

(ii) Peak Load by Region

The energy consumption by region for the interconnected system for the period from 1980 to 1986 is shown in Table 2.1.4.

In 1986, the percentages of the regional peak loads to the total were as follows:

Region	Peak load (MW)	Share (%)
Arusha	15.8	8.1
Moshi	10.9	5.6
Tanga	24.3	12.5
Dar es Salaam	91.0	46.7
Zanzibar	8.6	4.4
Morogoro	11.6	6.0
Iringa	17.8	9.1
Dodoma	4.2	2.2
Singida	1.6	0.8
Mbeya	9.0	4.6
Total (combined)	194.8	100.0
Coincident peak load	183.1 (Diversity factor	94.0 %)

(4) Load Pattern

(i) Daily Load Curve

Daily load curves show two peaks. The first generally occurs between 11:00 to 12:00 o'clock, and the second at about 20:00 o'clock.

For the Dar es Salaam district, the noon peak exceeds the evening peak. For all other towns in the interconnected system, however, the evening peak is higher than the noon peak.

A typical (1987) daily load curve of the interconnected system is shown in Fig. 2.1.4.

(ii) Monthly Load Variation

Temperature in Tanzania is almost constant throughout the year, so that, for both the interconnected system and isolated system, there are no significant variations for monthly loads.

Monthly load variation in 1986 was as follows:

	Interconnected system		Isolated systems	
Month	Monthly peak (MW)	Ratio to annual peak	Monthly peak (MW)	Ratio to annual peak
January	157.4	0.86	19.3	0.86
February	161.8	0.88	20.5	0.92
March	167.2	0.91	18.8	0.84
April	162.1	0.89	18.9	0.84
May	172.7	0.94	21.1	0.94
June	167.6	0.92	21.3	0.95
July	175.8	0.96	21.7	0.97
August	178.0	0.97	21.4	0.96
September	175.3	0.96	22.4	1.00
October	183.1	1.00	20.8	0.93
November	173.6	0.95	22.4	1.00
December	175.5	0.96	20.7	0.92

Note: The underlines indicate the maximum values.

2.1.4 Features of the Existing Power System

This section describes the features of the existing power system in Tanzania's eastern and northeastern regions.

The electrical power system facilities are indicated in Fig. 2.1.3.

(1) Power Supply Conditions by Regions

(i) Dar es Salaam Region

Dar es Salaam, through the Ubungo substation, consumes most of the power generated by the Kidatu power station. Small-scale diesel and gas turbine generating units are installed in the area for standby use.

(ii) Tanga Region

The total output of Hale and Pangani Falls power stations exceeds the power demand of this region. The excess power is exported to other regions.

(iii) Moshi Region

The generating facilities of the Kikuletwa (hydro) and the Arusha (diesel) power stations have deteriorated with age and cannot generate their rated outputs, while Nyumba Ya Mungu power station is now being operated in normal condition. The total supply capability, however, is less than this region's demand. The power shortage must be made up by transmission, over long-distance lines, from the Kidatu power station.

(2) Voltage Control

The interconnected system consists of long-distance transmission lines, and load consuming areas are generally located very far from power stations. The distance from Njiro substation in Arusha to its main power power source, the Kidatu power station, is approximately 700 km. This configuration of the interconnected system causes large voltage fluctuation.

The major reasons for the voltage drop in the 220 kV transmission line in the eastern region are as follows.

- Only the Kidatu power station is available for controlling the system voltage for the region.
- The major power flow to the east from the Kidatu station is to Ubungo, which causes a large voltage drop.
- Since the load on the system from the west side of Kidatu power station (Mbeya-Dodoma) is small, the system voltage rises as a result of the Ferranti phenomena. It, therefore, becomes difficult to raise the system voltage in the eastern region.
- It is difficult for the Kidatu power station, by itself, to control the above two contradictory voltage characteristics mentioned above. The bus bar voltages at respective substations are described below.

(i) Ubungo Substation

The bus bar voltages recorded on 21 September 1987 at 11:00 o'clock were as follows:

	220 kV	132 kV	33 kV
Bus bar voltage (kV)	186	131	34.8 *
Voltage drop (%)	-15.45	-0.76	+5.45
Transformer tap (%)	±20	-	-

(Note): * Values were read from meters mounted on control panel.

A voltage drop of -15.45% at 220 kV bus bar is very high. On the other hand, the transformer tap was able to maintain the voltage at the 33 kV bus bar above its rated 33 kV.

(ii) Morogoro Substation

The bus bar voltages recorded on 22 September 1987 at 13:00 o'clock were as follows:

	220 kV	132 kV
Bus bar voltage (kV)	208	128
Voltage drop (%)	-5.95	-3.03
Transformer tap (%)	±15	-

The bus bar voltages at the Kidatu power station and the Morogoro substation on 22 September 1987 at 13:00 o'clock were as follows:

	Morogoro	Kidatu
220 kV bus bar voltage (kV)	208	218
Voltage drop (%)	-5.45	-0.909
Condition of power flow (MW ± jMVAR)	100.9-j20.2	-

Under the above power flow conditions, the voltage drop between the Morogoro substation and the Kidatu power station is 4.59%.

(iii) Chalinze Substation

The 132 kV bus bar voltage recorded on 22 September 1987 at 16:00 o'clock was as follows:

	132 kV
Bus bar voltage (kV)	132-133
Voltage drop (%)	0-+0.758
Transformer tap (%)	+5-15

(iv) Njiro Substation

The 132 kV bus bar voltages recorded on 24 September 1987 at 3:00 o'clock and at 19:00 o'clock were as follows:

	132 kV	
	03:00	19:00
Bus bar voltage (kV)	133	110
Voltage drop (%)	+0.76	-16.6
Transformer tap (%)	±10	

The voltage drop of -16.6% at the 132 kV bus bar exceeds the transformer voltage control range of tap by ±10%.

Improvement of voltage drop has to be studied from standpoints of both transmission and distribution facilities and of supply and demand balance.

(v) Arusha Power Station

The 33 kV bus bar voltages recorded on 24 September 1987 were as follows:

	33 kV	
	03:00	19:00
Bus bar voltage (kV)	34	31
Voltage drop (%)	+3.03	-6.06
Transformer tap (%)	±10	

(vi) Kiyungi Substation

The bus bar voltages recorded on 24 September 1987 were as follows:

	33 kV		66 kV		132 kV	
	03:00	19:00	03:00	19:00	03:00	19:00
Bus bar voltage (kV)	-	33	70	63	135	107*
Variation (%)	-	0	+6.06	-4.5	+2.27	-18.94
Tap ratio (%)	-		-		+5	-15

(Note): "*" Inclusive of indicating meter error.

(vii) Kikuletwa Power Station

No indicating meter for the 33 kV bus bar is installed.

(viii) Nyumba Ya Mungu Power Station

The generator output, the 11 kV and 66 kV bus bar voltages and the power factors recorded on 3 October 1987 were as follows:

	03:00	19:00
Generator output (MW)	3.6	3.6
Generator voltage (kV)	11.2	10.8
Bus bar voltage (kV)	69.5	64
Power factor (%lag)	99	80

(ix) Same Substation

The 132 kV bus bar voltages recorded on 3 October 1987 at 13:00 o'clock were as follows:

	132 kV	33 kV
Bus bar voltage (kV)	122	No indicating meter
Voltage drop (%)	-7.58	
Transformer tap (%)	+5-15	

2.2 POWER DEMAND FORECAST

2.2.1 Economic Background

(1) National Economy

(i) General Situation

Growth in electricity consumption is closely related to the growth in the national economy.

Tanzania's economy developed steadily during the 1970's, but becomes stagnant from 1979 to about the end of 1985, during which time the Gross Domestic Product (GDP) remained virtually unchanged.

Table 2.2.1 shows real GDP growth per economic sector using 1976 as a base from 1973 to 1984. The Table shows that, from 1979 to 1984, agricultural sector and in service sector, production grew at the slow yearly averages of 2.3% and 2.6%, respectively, while industrial production plummeted at an average rate of -10.7% per year, with its share of GDP falling from about 17% (in 1979) to about 9.6% (in 1984).

Sector	Average annual growth rate of GDP 1973 - 1979	1979 - 1984
Agricultural	2.4%	2.3%
Service	5.7%	2.6%
Industrial	2.4%	-10.7%
Total GDP	3.6%	0.6%

The healthy growth of economy activities depends on an availability of foreign exchange. In Tanzania, a lack of foreign exchange has led to a chronic shortage of imported oil products and to unavailability of imported spare parts for industries. The industrial capacity utilization factor has thus fallen down to about 20 to 30%.

The government has been negotiating with IMF since 1979, when the country's balance of payments was rapidly worsening, to arrange standby credit. A mutual understanding with the IMF regarding revitalization was reached in 1986.

(ii) Economic Recovery Program

To help achieve recovery, the government implemented a Structural Adjustment Program (SAP) for the period from 1982 to 1985, and, in June 1986, an Economic Recovery Program (ERP) covering the period from 1986 to 1989. The latter program aims at achieving an average annual GDP growth of 4.5%. The strategies of the program are as follows:

- To increase agricultural production, particularly of cash crops.

- To provide priority allocation of foreign exchange to industries, in order to raise the capacity utilization factor from the present 20-30% to 60-70%.

- To rehabilite the infrastructure - transport, communication, energy, water supply, etc. - in preference to implementing new capital projects.

The funds required for ERP are estimated at about US$4,574 million, with 82% in the form of foreign exchange. The success of ERP, therefore, depends largely on IMF credit and on economic aid from foreign countries.

From about 1983, and in line with IMF recommendations, promotion of economic structural reform has slowly increased, at the same time, there has been an increase in exchange inflow through grants and loans from many countries. As foreign exchange increases, the GDP growth rates of all economic sectors are expected also to gradually increase.

(2) Electricity Pricing

Since 1973, the electricity tariff has been raised several times, in accord with the price rise of general commodites. The average rate per unit sold corresponding to each tariff amendment is as follows:

Year of amendment	Average rate (cents/kWh)
1973	26.14
1976	40.34
1979	64.38
1983	104.60
1984	132.81
1985	196.96
1986	294.53

The above shows that, from 1973 to 1986, the electricity tariff rose an average of 20.5% per year. During the same period, however, the consumers price index rose from 62.3 (1973) to 960.4 (1986), or at an average rate of 23.4% per year. In real terms, then, the electricity tariff declined at an average rate of about 3% per year.

Below are shown the average rates per unit sold, both at current prices and in real terms for 1973 to 1986.

Year	Current price (cents/kWh)	Consumers price index (1976=100)	Real terms (cents/kWh)
1973	26.14	62.3	41.96
1974	30.74	67.2	45.74
1975	31.85	90.2	35.31
1976	40.34	100.0	40.34
1977	48.27	111.5	43.29
1978	48.44	119.7	40.47
1979	45.13	137.7	32.77
1980	64.38	163.9	39.28
1981	65.58	214.7	30.54
1982	70.60	267.2	26.42
1983	104.60	354.1	29.54
1984	132.81	449.2	29.57
1985	196.96	513.2 *	38.38
1986	294.53	960.4 *	31.08

(Note): * Consumers price index for 1985 and 1986 was estimated based on currency exchange rates (Tsh vs US$) published in the "International Financial Statistics 1987" of IMF.

(3) Conditions in the Arusha-Kilimanjaro Regions

The proposed hydro power projects are located in the Kilimanjaro region, which is comprised of Moshi and many other small villages. Arusha is situated about 75 km west of Moshi. Arusha and the Kilimanjaro region are generally referred to as the country's Northern region. There are three substations in the Northern Region - Njiro, Kiyungi and Same. Kilimanjaro International Airport is located between Arusha and Moshi.

In 1986, energy consumption in Arusha was 64.03 GWh, and in Moshi 43.79 GWh. The total 107.82 GWh, represented 13.1% of the total consumption in the whole grid system. Coincident peak load in the same year was 26.7 MW. For the period from January to September, 1987, peak load increased to 16.7 MW in Arusha, and to 11.6 MW in Moshi.

From 1980 to 1986, the growth in electricty demand from the Northern region was higher than that from any other region in the grid system.

(i) Arusha

1986 energy consumption by consumer category was as follows:

62.1% for industrial, 28.7% for domestic, and 8.7% for commercial. Domestic energy consumption per consumer was twice as high in Arusha as it was in Moshi, indicating the higher standard of living of the former.

Unlike, Moshi, however, the Arusha region has no large plantations producing cash crops (sugar cane, coffee, cotton, sisal, etc.). There are only small scale coffee factories.

But, Arusha is home to many industrial factories including:

- General Tyre
- Sunflag (textile)
- KILTEX (textile)
- Fibreboard
- Breweries
- National Milling
- A-Z Textile
- TANELEC (manufacturing transformer)
- ALFI Chemicals

In 1986, electricity consumers in Arusha numbered 7,160, out of a total population of 1,227 thousand (245 thousand families). In other words, access to electricity in 1986 was only 3%.

(ii) Moshi

1986 energy consumption by consumer category was almost the same in Moshi as in Arusha: 60.0.% for industrial, 27.8% for domestic and 11.4% for commercial.

Unlike Arusha, Moshi has many large plantations, which produce sugar cane, coffee, cotton, sisal, etc.

The electricity consumption per industrial consumer is about 66% that of the Arusha region. The major factories are:

- KIBO Pulp and Paper Board
- TPC (sugar)
- Malting Plant
- Tanzania Bag
- Tanzania Tanneries
- Machine Tool
- Coffee curing
- KIBO Match
- Crate Manufacturers
- Breweries

Other large consumers are:

- Kilimanjaro Christian Medical Center
- Kilimanjaro International Airport
- Moshi Hotel

The Kilimanjaro region has an area of 13,209 sq. km and a population of 1,239 thousand (248 thousand families). In 1986, the number of electricity consumers was 10,364. This represents a rate of access of only 4.2%

Many large-scale irrigation and water pumping projects are being planned for this region:

- Lower Moshi irrigation project (2,300 ha)
- Post harvest facilities project (paddy processing facilities)
- Ndung irrigation project (680 ha) - Post harvest facilities
- Miwaleni pumping scheme (2,000 ha)
- Underground water study in Rombo and Hai (5,000 ha)
- Coffee pulper project - small centers for treating coffee before it is sent to the central factory
- Mkomazi valley project

In the industrial sector, KIDC (Kilimanjaro Industrial Development Center) is conducting training aimed at further for developing the local industries which include carpentry, ceramics, and foundries, etc.

2.2.2 Methodology for Power Demand Forecast

(1) Demand Relationship

It is well known that there is a close relationship between electric consumption and GDP. This relationship is frequently used as a basis for forecasting electricity demand. The power demand forecast in "TANESCO Power Sector Master Plan-1985", and the updated forecast of 1987, adopt a simple linear regression between GDP and electric consumption.

It is appropriate, in addition to GDP, to use, as a second explanatory variable, the average rate per unit sold. This is because the demand function for a given commodity generally consists of prices and income.

Tables 2.1.2 and 2.2.1 show, respectively, the annual energy consumption and the real GDP (based on 1976 prices) for 1973 to 1984. The average real rate per unit sold (based on 1976 price) is shown in Section 2.2.1 (2).

The relationship of these three parameters is given in Fig. 2.2.1. This figure shows roughly that in spite of sluggish GDP growth, a relative decline in the price of electricity has supported steady growth in energy consumption.

(2) Multiple Regression

The Data (in Tables 2.1.2 and 2.2.1 and in Section 2.2.1 (2)) on the energy consumption, GDP, and average rate per unit sold, lead to the following regression models. 1983 and 1984 energy consumption was adjusted to represent 84% of total energy generation. This was done because of unidentified consumption in those years, as described in Section 2.2.2 (3).

Y : Energy consumption (GWh)
X1 : GDP (Tsh million in 1976 prices)
S2 : Average rate per unit sold (cents/kWh in 1976 prices)

- For the grid system:

$$Y = 0.03810\ X1 - 6.8320\ X2 - 108.20$$
$$(R^2 = 0.84,\ s = 34.17)$$

- For the isolated systems:

$$Y = 0.006653\ X1 - 1.73596\ X2 - 0.25$$
$$(R^2 = 0.83,\ s = 7.06)$$

For application to the period from 1987 to 1990, the above equations were adjusted, taking account of a sudden demand growth in 1985/86, to yield:

- For the grid system:

$$Y = 0.03810\ X1 - 6.8320\ X2 + 22.73$$

- For the isolated systems:

$$Y = 0.006653\ X1 - 1.73596\ X2 - 35.91$$

For the application for 1990 onwards, the equations shown above were again adjusted. The adjustment takes into account an expected rapid demand growth as industrial consumers presently waiting to be connected (listed in Table 2.2.3) come on line. The adjusted equations are as follows:

- For the grid system:

$$Y = 0.3810\ X1 - 6.8320\ X2 + 157.81$$

- For the isolated systems:

$$Y = 0.006653\ X1 - 1.73596\ X2 - 82.59$$

(3) Assumptions Used in Formulating the Power Demand Forecast

(i) Forecast of Economic Performance

Because demand for electricity is directly related to economic performance, the timing of economic recovery and the expected GDP growth rates are of prime importance to forecasting electricity demand.

The following assumptions regarding economic performance were used.

(A) Transition period (1985 - 1990)

Data on actual and planned economic performance were not available for this period. Instead, estimated values were used, which are based on the inflow of foreign exchange resulting from international economic cooperation beginning in 1986.

a) Agricultural sector

Agriculture dominates the national economy. Agriculture accounts for the largest share of GDP, and is also the prime foreign exchange earner.

As mentioned in 2.2.1, the agricultural sector grew at an average annual rate of 2.4% from 1973 to 1979, and at 2.3% from 1979 to 1984. Authorization of private ownership of parts of plantations can be expected to have some effect in increasing incentives and production. The forecast growth rate for agricultural production was as follows:

Year	GDP growth rate
1985-1987	2.5%
1988	3.0%
1989	3.5%
1990	3.5%

b) Service sector

The service sector maintained steady annual growth of about 5.7% from 1973 to 1979, but, annual growth then dropped to about 2.6% through 1984. It is noteworthy that, from 1979 to 1984, production in the commercial portion of the service sector decreased at an average annual rate of -0.5%, but production in the administration subsector grew at an average rate of 7.5% annually, so that overall service sector growth averaged 2.6% per year. On the basis of these conditions, production in the service sector was forecast to grow at the following rates:

Year	GDP growth rate
1985-1987	2.6%
1988	3.0%
1989	4.0%
1990	5.0%

c) Industrial sector

From 1973 to 1977, the average annual growth rate of industrial production was 2.4%. Under a government strategy emphasizing domestic substitution for imported products, the manufacturing subsector achieved 3.6% annual growth during this period. Manufacturing production then dropped dramatically, however, due to shortages of spare parts and raw materials.

Based on the strategies outlined in ERP, the industrial capacity utilization factor is expected to rise from the present level of 20-30%, and to reach 60-70% by the end of 1989. Taking these conditions into account, industrial production was forecast to grow at the following rates, and the production levels of 1979/80 were expected to be restored by 1990.

Year	GDP growth rate
1985	0%
1986	5%
1987	10%
1988	10%
1989	15%
1990	15%

(B) Long-term (1990-2005)

A long-term forecast must be based on at the historical growth of the national economy, on the changes presently taking place, and on the strategies adopted by the government.

During the 1973-to-1979 period of healthy economic growth, the average annual GDP increase in the agricultural sector, was 2.4%; in the service sector, 5.7%; and in the industrial sector, 2.4% (and 3.6% in the manufacturing subsector). In 1979, agriculture accounted for about 42%, the service sector for 40%, and the industrial sector for 18% of total GDP. By 1984, due to the industrial recession, these percentages had changed to 46% for agriculture, 44% for the service sector, and less than 10% for the industrial sector.

Data are not available that would allow a realistic forecast of future GDP allocation, but it is not unreasonable to assume a long-term continuation of the 1979 GDP allocation.

The government target for annual GDP growth is 4.5%. On this basis, the following GDP growth rates were assumed in this study:

	Annual growth rate of GDP	
Sector	Base Scenario	Low growth Scenario
Agricultural	4.4%	3.9%
Service	4.0%	3.5%
Industrial	6.2%	5.7%
Total	4.5%	4.0%

The forecast for economic performance is given in Table 2.2.2.

(ii) Conditions of the Power System

Energy loss factor, load factor, peak load diversity factors, and regional power demand were estimated as follows:

(A) Energy loss factor

The energy loss factors recorded in the interconnected grid system during the 1973-to-1979 period were approximately 16%. This is considered to be an acceptable level, and it can be assumed that the consumption and sales were equal during this period.

From 1983 to 1986, however, there was a significant increase in the apparent losses in the grid system, with a loss of 20.6% in 1983, and of 21.7% in 1985. This increase is said to be due either to theft or to accounting difficulties. The problem of unidentified consumption is a serious one, and considerable effort and time would be required to solve it.

In the isolated systems, the average of the energy loss factors of recent years is 17.5%.

This power demand forecast was made using an energy loss factor of 21% for the grid system (16% for identified consumption and 5% for unidentified consumption), and of 17.5% for the isolated systems.

(B) Load factor

Annual load factor for the grid system was maintained at about 66% to 67% from 1980 to 1983, then dropped to 63.4% in 1984, and to 59.2% in 1985. In 1986 the load factor rose to 64.9%. The average load factor for the 1980 to 1986 period was about 65%.

For the isolated systems, the load factor from 1980 to 1986 was almost constant at about 48%.

The power demand forecast used a load factor of 65% for the grid system, and of 48% for the isolated systems.

(C) Diversity factor of peak loads

As the grid system expands, the isolated systems will gradually become corporated into it. Based on the monthly peak load data for 1986, a diversity factor of 0.94 was used for integrated peak load by region within the interconnected system, and a diversity factor of 0.99 for integrated peak load in the interconnected and isolated systems.

(D) Power demand by region

Although there is no question that regional power demand will change in the future, the available data do not permit these changes to be forecast. The regional power demand for 1987 to 1990 was, therefore, forecast using the 1986 regional percentages. By 1990, however, connection of waiting industrial consumers to the grid system will bring about anticipated changes. The regional power demand for 1991 onwards was, therefore, forecast using the estimated percentages for 1990. Demand percentages used for these two periods are as follows:

Region	For 1987 - 1990 Energy Consumption (%)	For 1987 - 1990 Peak load (%)	For 1991 - 2005 Energy Consumption (%)	For 1991 - 2005 Peak load (%)
Arusha	7.8	8.1	7.2	8.2
Moshi	5.3	5.6	4.7	5.5
Tanga	10.4	12.5	9.2	12.2
Dar es Salaam	50.5	46.7	45.6	46.5
Zanzibar	5.1	4.4	4.5	4.3
Morogoro	8.0	6.0	7.5	6.2
Iringa	7.7	9.1	16.4	9.2
Dodoma	1.6	2.2	1.5	2.2
Singida	0.4	0.8	0.4	0.8
Mbeya	3.2	4.6	3.0	4.9
Total	100.0	100.0	100.0	100.0