EVALUATION OF NORWEGIAN ASSISTANCE TO
THE ENERGY SECTOR OF SADCC COUNTRIES

PROJECT PROFILE 1:

THE LICHINGA HYDROPOWER PROJECT

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une, 1990

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P R O J E C T P R O F I L E 1:

T H E L I C H I N G A
H Y D R O P O W E R P R O J E C T

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L I S T O F T A B L E S

LIST OF ABBREVIATIONS

EDM	-	Electricidade de Mozambique
FDR	-	Final Design Report
FHR	-	Final History Report
GJ	-	gigajoule (= 10^9 joule)
GWh	-	gigawatthour (= 10^6 KWh)
ha	-	hectare
HCB	-	Hidroelectrica de Cahora Bassa
HEP	-	hydroelectric power
km	-	kilometre
kv	-	kilovolt
km^2	-	square kilometre
KVA	-	kilovoltamere
KW (or kW)	-	kilowatt
KWh (or kWh)	-	kilowatthour (= 10^3kWh)
m^3	-	cubic metre
m^3/s	-	cubic metre per second
MJ	-	megajoule (= 10^6 joule)
mm	-	millimetres
MPAN	-	Moagem de Produtos Agricolas do Norte
MT	-	metical (plural: meticais)
MW	-	megawatt (= 10^3 KW)
MWh	-	megawatthour (= 10^3 KWh)
NARSE	-	New and Renewable Source of Energy
NOK	-	Norwegian Kroner
%	-	percent
SADCC	-	Southern African Development Coordination Conference
t	-	tonne
toe	-	tonnes of oil equipments
TWh	-	terawatthour (= 10^{12} kilowatthour)
US $	-	U.S. Dollar

1. THE LICHINGA HYDROPOWER PROJECT

1.1 Brief description of the project area

1.1.1 Introduction

The Government of Mozambique has embarked on a policy to develop remote areas of the country partly to raise production and partly to reverse the present trend of rural population movement to the urban areas. The electrification of rural towns was recognised by the government of Mozambique as an important prerequisite in this strategy of rural development.

Despite the availability of power from Cahora Bassa, it is uneconomic to provide power to all rural towns. The anticipated loads are too small and the distances too great to justify the construction of transmission lines from Cahora Bassa to many of these towns. Hence, Electricidade de Mozambique (EDM) is exploring other options. One such option is diesel generators, but this option is both expensive and unreliable because the war situation and the deteriorating economy have affected both diesel supplies and spare part provision. Another option is mini-hydropower projects.

The difficulties of diesel generation prompted EDM to commission NORCONSULT to examine the range of possibilities to supply electricity to six centres in the northern provinces. Of these, Niassa Province was given the highest priority and two centres, Lichinga, the provincial capital, and Cuamba, a district capital, were selected. Both had been provided with diesel generators but were experiencing increasing difficulties in obtaining adequate diesel supplies.

1.1.2 Lichinga town and its environs

Lichinga, the capital of Niassa Province in northern Mozambique, is situated on a Plateau some 1,365 metres above sea-level. Villa Cabral, the name of Lichinga between 1945 and 1975, was given town status on 23rd September, 1962. Since 1954, it has been the principal administrative centre of Niassa Province. Lichinga lies 800 kilometres inland by road or rail from the coast and about 1400 kilometres north of Maputo. It is linked to the rest of Mozambique by air, road and rail and is the final station of the railway line from Nacala, on the Indian Ocean, to Malawi. Road connections with the rest of Mozambique during the rainy season are not good and there is, therefore, a heavy reliance on rail transport for supplies. Since 1982, war has disrupted rail services. The most reliable form of transport is air.

The town has an adequate infrastructure for a rural centre. It has an airport, a provincial hospital, water works, primary, secondary and technical schools and the provincial administration.

1.1.3 Energy situation prior to the hydropower project

The main sources of household energy are kerosene for lighting and charcoal and fuelwood for cooking. Some households, the public service sector and industry use electricity.

Prior to the commissioning of the Lichinga Hydropower Project in 1983, electricity was supplied by three diesel operated generators. Two generators were 532 KW each and a smaller one was 150 KW. All generators were operated by EDM.

Electricity generation was sufficient to meet the power needs of Lichinga which seldom exceeded 500 KWh. Generation remained constant at about 2.57 GWh per year. In 1979, 2.57 GWh was produced with a peak demand of 595 KW. Generation remained constant at some 2.45 GWh up to 1981. In 1982, there was a sharp increase of some 20 per cent and annual generation reached 3.17 GWh. By that time, diesel shortages affected output which began to fall. At the time of the visit of the evaluation team, the plant was operating only 7.5 hours a day, from 1530 to 2300 hours.

Over the same period, the demand for electricity increased - the customer base grew from some 650 in 1978 to 990 in 1982. Seventy five per cent of the connections were households using electricity mainly for domestic lighting and accounting for about 39 per cent of the total sales in 1982.

1.2. Background and objectives of the project.

An agreement between the governments of Norway and The People's Republic of Mozambique regarding hydropower studies and development was signed in April 1980. The Norwegian company Norconsult A/S was appointed consultant, and the contract between NORAD and Norconsult was ratified in August 1980.

Study and analysis of the hydropower potentials of Lucheringo River in Niassa Province was part of the contract. A working paper submitted by Norconsult in September 1980 concluded that a hydropower project near Lichinga town appeared to be promising, and additional studies were recommended.

Lichinga had and still has a thermal power station equipped with three diesel-driven generators: two Blackstone generators with a peak capacity of 532 KW each, installed in 1975; and one very old and worn-down Deutz generator with a peak capacity of 150 KW.

The growing interest in hydropower was a consequence of the fact that diesel fuel was becoming increasingly expensive and scarce in remote regions such as Niassa. Already around 1980, there were temporary shortages of diesel fuel and lubricants as well as spare parts for the generators. By switching electricity production to hydropower, the government of Mozambique hoped to save scarce foreign exchange and improve reliability of electricity supply.

It should also be noted that the remote and relatively underdeveloped Niassa Province held and still holds a special position in the development priorities of the government. In order to achieve development in the area it was considered necessary to make Lichinga, which in the capital city of the province, an attractive administrative and services centre. One of the means to achieve this, would be to improve the reliability of electricity supply to Lichinga town.

In March 1981, Norsonsult submitted a Design Report for the Lichinga Hydropower Project. The report concluded that construction of a hydropower plant to be backed up by diesel generation in the existing thermal power plant was economically viable. An agreement for construction of the project was signed in May 1981, and a contract between NORAD and Norconsult covering detailed design, procurement, construction management and training was signed in February 1982.

Construction activities, however, were initiated already in May 1981.

1.3 Project implementation

1.3.1 Project identification and selection

Lichinga was the first project of this kind to be implemented in a series of similar projects. EDM, as the responsible organisation, wanted to gain experience and skills in construction, operation and maintenance of small hydropower plants. A fundamental concept was that equipment and key personnel would be transferred to other projects after the Lichinga project was completed.

The Norwegian authorities found the Lichinga hydropower project promising and concluded that the project possessed fundamental elements of Norwegian support policy, such as

- The project represented well known technology
- Operation and maintenance costs after completion of the project, would be modest.
- The project would imply significant transfer of technology through on-the-job training of staff.
- The project would provide a reliable power supply and provide for regional development.

The team wants to point out that this conclusion must have been based on the assumption that the existing diesel power plant at Lichinga town would also be properly operated and with reliable supply of diesel fuel, the reason being that the Lichinga hydropower plant is basically a run-of-river plant with only a small reservoir of 66000 m^3 for daily peaking. In the rainy season it will provide both energy supply and peaking power, while in the dry season it can only provide power a few hours per week. Unfortunately, through the later part of the 1980s diesel fuel has been scarce or not available at Lichinga and thus electricity has only been available for a few hours per day during the dry season.

Based on the reports and the above conclusions, agreement between Norway and Mozambique, for implementation of the project was signed in May 1981. The contract (a project implementation and management contract) between NORAD and Norconsult A.S. was finalised in February 1982, covering detailed design, procurement, construction management, and training.

The scope of work in the contract listed the following services:

- Procurement of construction equipment and materials.
- Procurement of permanent electrical and mechanical equipment.
- Detailed design, including work drawings and specifications.
- Shop inspection and approval of hydraulic, mechanical and electrical equipment, besides interphasing of manufacturing and civil works.
- Project management, progress- and cost control.
- Construction management, supervision and quality control.
- Assistance during erection, testing and commissioning of permanent equipment.
- Practical and theoretical training of construction workers and local personnel on all levels.

Final responsibility for project implementation should rest with EDM.

1.3.2 Project design and choice of technology

The Lichinga hydropower plant located about 10 km east of the town of Lichinga, develops a gross head of 52 m in the upper reaches of Lucheringo River. The main project components are the intake dam, the headrace culvert, the serge chamber and penstock, the power station and a short tailrace channel.

The 12 m high concrete gravity dam is built with earth fill end sections, with impervious concrete core. The 57 m long, ungated spillway, designed for a flood of 100 m^3/s, is incorporated in the gravity dam section. The total dam crest length is 130 m.

The dam forms a reservoir with a live storage of 66000 m^3. The drainage area catchment at the dam site is 50 km^2 and the mean discharge in Lucheringo River at the same point 0,8 m^3/s, equal to 25 mill m^3 in mean annual run-off. Thus the reservoir volume is 0,25% of the annual run-off, i.e. the reservoir can serve as daily peaking, only.

The 2475 m long headrace is designed and built as a closed concrete culvert, cross section (B x H) 1.2 x 1.5 m. The culvert is spanning swamping areas on concrete pits in two places, some 180 m and 480 m, respectively, and the culvert is crossing a small creek on a bridge. Air-vents and manholes for inspection and maintenance are provided along the culvert. A service gate and a track rack is located at the intake dam.

The surge chamber, necessary to even out pressure surges at local variations and providing operational stability, is built as a 6.0 m diameter cylinder, height 15.5 m. The 280 m long penstock is made of 1000 mm diameter ductile cast iron pipe. A gate and a trash rack is provided at the inlet to the penstock.

The power station consists of a 6.5 x 10.0 m concrete building with attached workshop area entrance with staircase. The power house contains the standard electro-mechanical equipment for single unit generation stations, i.e. a main valve, a 730 kW horizontal Francis turbine, a 850 kVA 3-phase synchronous generator, governor and lubricating oil aggregate. The power house also contains an area for loading and erection works. The outdoor switch yard contains the generator transformer, the circuit breaker and current transformer, the line connection tower with insulation switches, lightning asserters and voltage transformer, and auxiliary service transformer.

Included in the project is also the Lichinga substation with a 100 kVA transformer.

The team had the opportunity to inspect the Lichinga hydropower plant. The general impression from the field as well as available technical data is that the power plant is well designed and well built. It was noted that part of the fencing around the switch yard had fallen down, thus leaving a high voltage area open for unauthorised access. Although the power house has an acceptable appearance, some repainting would make it look even nicer.

These are, of course, minor comments, but still considered important in line with the following reasoning. A hydropower station represents a very high cost investment and the necessary, though limited, maintenance must be given utmost attention. This is normally achieved by encouraging and providing means for the operating personnel to maintain a very high standard of appearance.

Appropriate choice of technology in hydropower development implies appropriate planning, design and construction procedures based on topography, hydrological characteristics, available materials and cost analysis.

The latest development in standardised electro mechanical equipment has been used at the Lichinga power plant. The main components, turbine, generator, transformer and control equipment is not available in Mozambique or other SADCC countries, and was thus imported from Norway. It was stated that crane, gates and other steel works are also not available in Mozambique and had to be imported.

No operational difficulties or faults were reported to the team, for the period it has been in operation, i.e. since late 1983.

With respect to appropriate planning and design two main components may be mentioned, the reservoir and the headrace culvert. The reservoir provided is very small, the live storage being only 0.25% of the mean annual flow in the river. The present generation is 1.52 GWh (Mozambique power studies, Volume 3, Rural Electrification Lichinga-Unango-Litunde, Norconsult, August 1988) while the estimated possible generation at the Lichinga hydropower plant is 2.0 GWh. The theoretical annual energy potential at the power plant site is only slightly higher than 2 GWh. A larger reservoir would, therefore, only provide some firm energy and firm peaking power, but would not increase the total annual energy output, significantly. This is mainly due to the fact that the power and energy demand at Lichinga town is higher than the generating capacity at the Lichinga hydropower station. A reservoir would provide power for the most pressing needs such as the hospital, other health care, water supply, etc. and the power shortage would be more evenly distributed over the year. The size of dam and reservoir needed and the cost involved would, however, not be acceptable from an economic feasibility point of view.

The cast-in-place concrete culvert chosen for the headrace is a somewhat unusual design. An alternative would have been concrete pipe, but pipe of this size was not available in the region and it was a basic concept to make use of local products and work force to be extent possible. Another alternative, most likely chosen in industrialised countries would have been glass fibre reinforced pipe. This would also imply imports and considerable spending of foreign currency. The concrete culvert was therefore the most labour-intensive alternative, which also allowed for considerable training and experience in concrete construction work, though it may not have been the least-cost alternative. Safety precautions due to sabotage action may also have been considered.

The topography at the site renders itself to still another alternative, an open canal solution. This would have eliminated the need for a surge chamber. Norconsult has informed us that an open canal was investigated and found approximately 3% cheaper. The culvert station was found to have several advantages, such as approximately 1.5 m higher head, less complicated operation and no loss of water due to leakage or load variations.

1.3.3 Implementation of the project compared with original plans and construction schedule

The construction works started in May 1981 by excavation and preparation of the dam foundation. Civil works and electromechanical works were then carried out simultaneously until commissioning in December 1983. The official inauguration, however, took place on September 15, 1983.

The deviations from the original time plan were minor and at the end were within one month. This must have implied a close follow up during construction.

Access to construction materials was an essential part of the project implementation, and the basic idea was to make use of products available locally or in the region, whenever possible.

- Lumber was brought in from Malawi. A smaller quantity from Cuamba found no proper utilisation, due to low quality.
- Crushed rock was taken from a local crushing plant approximately 30 km outside Lichinga. The plant had sufficient capacity to supply the construction works, but operational problems on account of lack of material occasionally caused delays at the site.
- Sand was available at the shores of Lake Niassa, some 60 km from the construction site. A major obstacle was the transport as the road conditions were difficult, especially in the wet season. However, lack of sand supply did not cause delays in the construction works.
- Locally produced cement was available and transported by rail from Nacala.
- Steel was partly available on the inland market, and approximately 75% was procured via EDM in Maputo. The remaining 25% was transported from Malawi, but again transport was a major obstacle, especially in the wet season.
- Lack of diesel supplies was a major cause of various delays.

All electro mechanical equipment had to be imported. For some of the items international tenders were called for. However, bearing in mind the limited size of the project, the highest number of invitations to submit bids was 5 (turbine). This was considered sufficient to reflect international price and quality levels.

For crane, gates and electrotechnical equipment (i.e. generator, transformer and substation equipment) only Norwegian bidders were invited.

The quality control and inspection of the various equipment components was handled by the consultant, Norconsult A.S., on behalf of the client. This is normal practice in Norway and many other countries.

Following the initial period of training and testing, the Lichinga hydropower plant has been operating successfully under direction of competent EDM staff.

The expatriate staffing during the construction of the Lichinga hydropower project was one construction manager and 8 foremen. (This was also the expatriate staffing at the Cuamba project when the construction started soon after Lichinga. Gradually the expatriate staffing there was reduced to one construction manager and 2 foremen).

The expatriate staff during construction of the Lichinga power plant was one site manager and eight foremen.

On-the-jobs training was a major objective of this project, the positive result of which was learned during construction of the Cuamba project later.

Some problems like road transport during the wet season are referred to above. Other problems were the shortage of local qualified foremen affecting the work at the various work stations. The responsibility for recruitment was placed on EDM. It was felt that the problems would have been more easily overcome if the site manager were given this responsibility.

Occasional disciplinary difficulties were also encountered, including irregularities in the daily registering, although this did not constitute any serious problem. Frequent delays in the scheduled payment of monthly salaries caused considerable unrest among the workers, without actually causing any delays at site, however.

It was underlined from the site management that administrative problems of this kind should be subject to thorough consideration before initiating the implementation of future projects.

A Problem of a totally different nature occurred regarding the financing of the project. When Norway decided to support the project a cofinancing with Mozambique was assumed. The Norwegian participation amounted to NOK 12 mill, whereas Mozambique through EDM was supposed to be responsible for manpower and equipment procurement in local currency equivalent to NOK 8 mill.

A major part of this equipment was not available on the inland market, and in order to ensure the progress of the project NORAD had to take over part of EDM's obligations. This lead to a need for extra funding in the order of NOK 2 mill.

Even though not a part of the project it is worth mentioning that the Lichinga hydropower plant was subject to training on a higher professional level, as a student from the Eduardo Mondlane University in Maputo fulfilled the final requirements for a degree in Mechanical Engineering with a thesis based on this project. The representative of Norconsult in Maputo was involved in formulating the task and supervising the work.

1.3.4. Assessment of costs and internal economies of the project

In the Design Report dated March 1981, the costs of the project at 1980-prices were estimated at US $ 3.39 mill., equivalent to approximately NOK 23.5 mill. This estimate included contingencies totalling US $ 506,000, but no allowance for cost inflation since it was based on (constant) 1980-prices.

The costs of constructing the power plant and of its operation and maintenance were compared with the only realistic alternative, viz. generation by means of diesel units. Hydropower plant with diesel back-up from the existing thermal power station was compared with a pure diesel alternative. The internal rate of return for hydropower with diesel back-up was determined from the combined cost streams with and without hydropower. The cost stream for "diesel only" was treated as a benefit to the hydro-plus-diesel-alternative.

At assumed annual fuel price increases of 3% and 5% in real terms, this gave internal rates of return of 7% and 10%, respectively.

Now, the Design Report stated that, "The opportunity cost of capital in Mozambique is considered to be between 10% and 15%". (p. 10-2). Using this as a criterion for decision, the project would hardly be economically viable. However, the Design Report added that,

> "An additional value over and above the benefit expressed through the presented cash flows may be attached to the fact that the hydropower plant will be the first to be constructed since Independence, and will be used for training for future projects. It is strategically located and easily accessible from Lichinga. Therefore it is possible to accept a lower internal rate of return than might otherwise have been the case. It is concluded that this project is economically sound" (p. 10-2).

The Final History Report, submitted by Norconsult in June 1984, shows that the total actual costs of the project amounted to US $ 4.18 mill., equivalent to NOK 28.8 mill. Of this total, NOK 19.7 mill. (68.4%) were foreign currency costs, whereas the remaining approximately NOK 9 mill. (31.6%) were local currency costs.

The Final History Report does not give any information on inflation during the construction period. If we assume that the annual rate of inflation was 10%, total estimated project cost (of NOK 23.5 mill.) should be escalated to approximately NOK 28 mill. which is very close to actual costs. Against this background, it cannot be argued that the project suffered any significant cost overrun. One reason for this is that high contingencies, totalling more than US $ 500,000 (15% of total estimated costs), were included in the cost estimates, which seems reasonable under the conditions then prevailing in northern Mozambique.

We would like to note that the costs of professional services (i.e. design, management etc.) performed by Norconsult amounted to NOK 6.9 mill, accounting for 35% of total foreign currency costs and 24% of total project costs. These figures are rather high although they may be explained by the special situation prevailing in Mozambique. In any event, NORAD and the consultant should try to find ways to reduce this cost item for possible future projects.

738 KW Investment cost per KW of installed capacity turned out to be US $ 5,726, equivalent to NOK 39,500. This is a rather high figure, especially when considering that we are actually dealing with a run-of-river project with large variations in energy production due to fluctuating discharge in the Lucheringo River, and therefore with a potential average annual energy production of only about 2 GWh. This implies an investment cost per unit of average annual energy production as high as NOK 14 per KWh.

However, when considering that Lichinga was a pilot project and that hydropower now accounts for more than 90% of electricity supply in Lichinga (due to lack of diesel and spare parts for the diesel generators), the costs of the Lichinga hydropower plant seem to be justified.

1.4 Economic considerations

1.4.1 Potential users of electricity

About 97 per cent of the population of Lichinga District is engaged in agriculture. Small-holder family farms, of 2 - 5 hectares, predominate. The main energy resource for agriculture is human labour. There are, however, some large mechanised farms which need electricity for irrigation, maize mills and various mechanical tools. These large farms have their own generators but most of these are not working because of the shortage of diesel and spare parts. The large farms are commercial enterprises employing between 40-50 permanent employees and between 100 - 300 temporary workers. The largest of these produced 810 tons of maize, 180 tons of potatoes per year, and also produced other crops. The provision of electricity could reduce the need for diesel.

Traditionally, there has been little large scale agricultural processing. Apart from some small oil processing plants, extracting oil from sunflower, the most important agro-industries are three electric and seven diesel operated flour mills. However, because of the lack of diesel, only the three electric mills are in operation. Even these operate only five hours a day due in part to inadequate power. The mills have a potential output of up to nine tons of maize a day. They provide a valuable service, particularly to women, and are an important source of urban employment. For instance, the Moagem de Produtos Agricolas do Norte (MPAN), the largest mill in Lichinga, has 76 employees and a capacity to mill about 1500 tons per annum. During peak periods, about 100 women queue each day outside the mill. Current production is however, only a fraction of the potential capacity.

There is also a private carpentry enterprise which employs about 45 skilled and unskilled workers. The factory works at 20 - 30 per cent of its capacity. Another important activity is the Construcao Integral de Niassa, producing tiles, bricks and prepared stonework.

Other potential users are public institutions such as the hospitals, the schools and the water supply system. The single largest number of consumers is the household sector which utilizes almost 40 per cent of generated power.

1.4.2 Energy use and trends

The existing hydropower station of 730 KW and the diesel generators with a capacity of 1214 KW in Lichinga Town, both operated by EDM, are the only public sources of power in the area. The combined installed capacity of 1944 KW can produce 5 GWh per annum but the amount of electricity generated has actually declined over the years from 3.17 GWh in 1982, before the hydropower was commissioned, to 1.67 GWh in 1987. Over the same period, hydropower increased from .05 GWh in 1983 to 1.52 in 1987. Between 1983, when the station was commissioned, and August 1988, some five million kilowatt hours have been produced, representing savings equivalent to 1,500,000 litres of diesel. Without hydropower, Lichinga town would have had little electricity. There is no baseline comparison available but the start up dates of small industries suggest that the commissioning of the hydropower station led to the setting up of some industrialisation.

NORCONSULT argues that there is suppressed demand in Lichinga and there is evidence to support this. In spite of the hydropower investment, electricity is supplied for a limited period only during some months of the year. The hydropower station does not have firm power. It operates for 24 hours a day only during the rainy season, December to May. During the rest of the year, it works twice a weak from 6 am to 9 pm. Many of the small industries operate below capacity and there are complaints about power shortages. NORCONSULT has put forward figures for adjusted electricity generation if the thermal units were operating at full capacity. (Table 1.4.1).

Table 1.4.1 Electricity consumers Lichinga (1978-87)
Adjusted Electricity Generation (GWh)

	1983	1984	1985	1986	1987
Actual generation	3.07	3.00	2.10	1.12	1.67
Adjusted generation	3.51	3.81	4.28	4.67	4.81

Source: NORCONSULT, 1989

The full potential of electricity to help economic development has to be seen against the current conditions in Mozambique. The benefits of rural electrification depend on the return of internal peace and economic stability. Many of the small industries operate at rates well below their capacity due, at least in part, to the lack of raw materials as well as the lack of sufficient energy. The disruptions caused by the war and the ensuing lack of security conditions have affected production quite drastically. Nevertheless, NORCONSULT forecast that the 1995 demand for Lichinga will be 7.02 GWh, rising to 9.25 GWh by the year 2000.

1.5 Social aspects

1.5.1 The setting

Population statistics for Lichinga differ widely, ranging from 38,000 to 70,000. These differences may be due to the definition of "town". Lichinga Town and its environs, including nearby villages and the small centres of Unango and Litunde, had approximately 70,000 inhabitants in the 1980 Census. By 1988, the population was estimated to be about 87,000 persons. In addition, there are uncertain numbers of displaced persons seeking refuge from the war. Finally there are unknown troop movements. Thus, the Town Administrator argued that there are 90,000 to 100,000 persons in and around Lichinga Town.

The available "physical quality of life" indicators reflect the low level of development in the area. Any improvement in the services, and the maintenance of the existing ones, is crucial to development. Table 1.3 contains the indicators.

Table 1.5.1 Indicators of physical quality of life

Life Expectancy	35.3 years
Infant mortality	219 per thousand
Illiteracy (male)	77 per cent
Illiteracy (female)	91 per cent
Primary School Attendance	11 per cent

The main components of the social infrastructure are the Provincial Hospital, the schools - primary, secondary and technical, and the piped water supply all of which are dependent on electricity. It was not possible to interview the personnel or collect data on the role of electricity for the maintenance and improvement of these services.

1.5.2 The impact of electricity

The only establishment visited was the provincial hospital. Here, it was clear that electricity was needed for a variety of functions such as cold storage for medicines, sterilisation of equipment, X-ray services, operating theatre functions, airconditioning of laboratories, X-ray room and operating theatre. The hospital has a small standby generator for emergency operations because of the frequent interruptions to and inadequacies of the power supply.

At present, the shortfall in the electricity supply during the dry season affects both the medical services and the supply of water to the hospital. Similar conclusions could also be drawn about the effect of the hydropower on the other services.

Another important benefit was that offered by the maize mills. This is especially beneficial to women. The long queues of 100 women or more at the mills indicate both the value of the service and the fact that the current milling capacity is insufficient. Once again the value of the Lichinga hydropower is demonstrated by the fact that out of seven mills, only three electric ones are working even if at below full capacity.

No data was available on the economic activity pattern of Lichinga Town, but the 1980 Census found that 91.3 per cent of the inhabitants of Lichinga Town and District were workers, 6.6 per cent students, 0.4 per cent domestic, 0.3 per cent other and 0.4 per cent unemployed. Of the 26,400 workers, 96.7 per cent were engaged in agriculture, mainly self-employed or working on family farms. This last distinction is very likely to be gender-related, since the total number of workers was divided as 11,277 males and 15,144 females. It is still basically a rural centre in which many of its inhabitants either depend entirely on agriculture or have small fields to supplement their other incomes.

The growth in the number of consumers even during the troubled times and even when the supply of electricity has been irregular suggests that there is an unfilled demand for electricity in the rural areas among some households. The initial cost of connection requires a substantial financial outlay. When the economic situation improves, demand is certain to increase from the present level of about 10 per cent of the households in Lichinga Town. For the majority of households, therefore, electricity does not even provide lighting. EDM argues that the electricity is not for full domestic use. Indeed for the majority of people, the benefits of rural electrification can only come about through the provision of better and greater economic opportunities and public services mentioned above.

In the short term, it is unlikely that electricity will have any impact on reducing the use of fuelwood and charcoal. Even those households that use electricity for lighting, the schools, small restaurants and the hospital, still use these two sources of energy for cooking and heating water. The resultant environmental problems caused by deforestation will not be resolved through electrification, neither will the burden of women having to collect fuelwood.

1.5.3 Present state of electricity supply and its implications

At present electricity from the Lichinga Hydropower Plant is available for 20 hours a day only during the rainy season. During the dry season, the hydropower plant operates twice a week from 6 a.m. to 9 p.m. The thermal plant operates daily but only from 3.30 p.m. to 11 p.m. There is a severe shortfall in electricity particularly during the dry season.

According to NORCONSULT (1988) there is a sizeable "suppressed demand". The data, parameters and trends of demand and shortfall may be debatable, not least because of the paucity of baseline economic data. There was no firm data on population, economic activities and the consumption pattern of industry. The war situation almost certainly distorts real demand and consumption. Nevertheless, the team was able to get first hand information on the general shortage of power supply and its implications.

The hospital at Lichinga is a major health facility, as it is the Consultant hospital for Niassa Province. It has a wide range of equipment and facilities (X-ray, operating theatres, cold storage rooms, blood banks, sterilisation equipment, blood testing facilities etc). Medical supplies are obtained through international NGOs and other international organisations; there is a good team of local staff.

The shortages of electricity affect the hospital badly. At the time of the visit of the team, the hospital was without regular power, and, worse still, without water. The water supply system of the town depends on electricity for pumping. The water storage tanks are small in capacity and water has to be pumped into them almost continuously. Water supply stops almost simultaneously with cuts in electricity. The irregularities in electricity supply also affect the hospital's capacity to deal with emergencies, particularly at night, when the operator of the emergency generator utilised for operations when electricity fails is off-duty.

The hospital is but one example only. Similar impacts are felt by individuals in order to fully benefit from hydropower, therefore, Lichinga Town needs additional energy for the generation of electricity.

1.6 Limitations of the Lichinga project and the question of implementing Mbahu.

1.6.1 The background

The Lichinga hydropower project was designed as a run-of-river plant implying large fluctuations of its energy production in accordance with fluctuations of the discharge in Lucheringo River. The idea was therefore that the hydropower-plant should get back-up from the existing thermal powerplant in Lichinga.

Since the early 1980s. Mozambique's balance of payments position has become increasingly worse. At present, diesel is available only occasionally in Niassa Province, and no foreign exchange is available to import necessary spare parts for the diesel-driven generators. The balance of payments crisis has also resulted in long interruptions and very low carrying-capacity of the railway which has to transport diesel up to Lichinga.

As a result of this situation, the thermal power station has in recent years been operating at very low rates of capacity utilisation also in the dry season when the hydropower plant can supply only quite insignificant amounts of energy. The production of thermal power fell from 2.4 GWh in 1984 to 0.2 GWh in 1987, and its share in total power production declined from 80% to about 10% in the same period. At the time of the team's visit in Lichinga, the thermal plant was operating only 7.5 hours a day from 3.30 p.m. to 11.00 p.m.

As a result of the low production of thermal power, the ratio between maximum and minimum generation of electricity has increased from 1.3 in 1978 to 2.0 in 1984 and 11.6 in 1987 (cf. NC: Rural electrification in Niassa, Vol. 3, 1988, p.3-4). On the other hand, thanks to the hydroplant, maximum monthly electricity generation increased from 0.219 GWh in 1978 to 0.313 GWh, corresponding to 3.76 GWh per year, in 1987. (ibid.). This is a clear indication of a considerable suppressed demand for electricity in Lichinga.

The low rate of operation of the thermal power plant has caused serious problems for major users of electricity, such as the water supply utility, which needs electricity for pumping water up to Lichinga town, and the hospitals. Due to electricity shortage, many industries in Lichinga operate at very low rates of capacity utilisation, and there are many complaints about the shortage of electricity.

The hydropower station is at present the only reliable source of electricity, but it can operate for 24 hours a day only during the raining season, from December to May.

The problems we have now indicated was the reason why EDM wanted to consider a second hydropower plant to supply electricity to Lichinga. Among several alternatives Mbahu was finally selected as the most interesting one.

1.6.2 Aspects of project selection

The Mbahu Hydropower Project, located some 30 km north-east of Lichinga on the Lucheringo River, is planned with a reservoir in order to provide firm power and energy. This is not the case for the existing Lichinga power plant, serving the same area, but built as a run-of-river power plant with a small intake pond only. To establish a reservoir at the Lichinga power plant to firm up the power and energy generation is technically and economically not feasible.

The Government of Mozambique is not planning to connect the project area (supply area) to the National Grid in the years to come. The distance to the nearest connection point on the National Grid is about 400 km to the south. The forecast loads are too small and the distances too great to justify the construction of a transmission line (according to Rural Electrification in Niassa, Volume 3, Norconsult Report, August 1988).

Considering the cost of several small hydropower plants, this conclusion is not necessarily obvious from a purely cost point of view. Abundant hydropower energy is available from the Cahora Bassa power plant on the Zambezi River and transmission lines can normally be built with less import of expatriates and foreign capital than when constructing new hydropower plants. One could in fact foresee a connecting transmission line leap north from

Cahora Bassa, across Malawi to Lichinga and connecting to the existing main line to Nacola.

It is understood, however, that this represents speculations only, with the war situation as it has developed during the 1980s. It would also involve negotiations with Malawi and maintenance of transmission lines through areas with rough terrain. The conclusion reached by the Government is fully understood, therefore, and the alternative choice has become implementation of small hydropower plants, in line with the growing demand.

The identification and selection process for the Mbahu Hydropower Project started in 1982. A reconnaissance study (Norconsult, 1982) investigated several potential small hydropower plants in the province and concluded that for the supply of power to Lichinga there were two suitable hydropower sites on Lucheringo river and one on Messinge river:

- Ilinga Hydropower Plant (Lucheringo)
- Maniamba (Messinge)
- B3 Hydropower Plant (Mbahu) (Lucheringo)

The Ilinga hydropower plant was assessed as being the most economical of the three closely followed by Maniamba. Two alternatives were considered for B3: a low dam (10 m) and a high dam (35 m) alternative. The B3 project, later named Mbahu, was found to have the largest firm power potential, although it was found to be the most expensive. Due to the more central location of Ilinga and Mbahu, EDM decided to proceed with studies of these two projects.

In 1986 a Selection Report concluded that the construction of the Mbahu hydropower project would require the lowest investment to meet the whole electricity demand up to about 1995. Although lower investment could be achieved at the Ilinga dam site, the larger reservoir at Mbahu would give a higher firm energy output.

This was considered an important factor since the supply of diesel fuel is so irregular that firm power generation at the thermal power plant in Lichinga was not possible.

Based on these studies and other studies available for the area, the team concludes that the Mbahu project seems to be the most suited selection for meeting growing energy demand through development of small hydropower potentials.

In addition to providing firm power to Lichinga the area for electricity supply also includes the rural corridors between Lichinga and Unango, and Lichinga and Litunda.

1.6.3 The layout of the project

The dam is proposed located at the upstream end of a series of rapids. The rapids have a natural head of 21 m. The proposed dam will have a maximum height of 26 m, providing a maximum head for power generation of 42.5 m.

The catchment area is 610 km^2 with a mean runoff of 7.5 m^3/s or 236 mill m^3 per year. The drawdown in the reservoir is proposed at 11 m providing a live storage of 30 mill m^3 or 12.7% of mean annual runoff.

It is proposed to install two Frances generating units, each with a design discharge of 3 m^3/s, a nominal capacity of 1000 KW, a capacity at maximum head of 1100 KW, and a capacity at minimum head of 690 KW, each.

The target firm power for the project is 1000 KW with a firm energy production of 8.8 GWh per year and a mean annual energy generation potential of 11.6 GWh.

The waterways consist of a headrace tunnel a culvert and a penstock, including a concrete surge tank. According to Mbahu Hydropower Project Technical Review Report, Norconsult, August

1988, two alternative rootings for the waterway have been investigated. The final choice is the least cost alternative, which is preferred also from a technical point of view.

The area downstream of the proposed Mbahu power plant has additional hydropower project potentials and possibly also other use of water. These possible future developments will benefit from the proposed reservoir.

The proposed Mbahu power plant is similar in design to the Lichinga power plant, but different to Cuamba. At the Mbahu power plant it is obviously the intention to make use of the experience gained from Lichinga. EDM has planned to transfer key personnel from Cuamba, many of these being previously trained at Lichinga. The team did not, within its time frame, have the opportunity to visit the Mbahu site. Review of the technical plans does not reflect any obvious alternative suggestions to the proposed layout and design. It is on the other hand clear that the plans reflect the design adopted for the previous projects in the area, to the extent possible, and in this way based on the experience gained.

1.6.4 Project costs of Mbahu

In the Technical Review of the Mbahu Hydropower Project (August 1988), Norconsult presents detailed cost estimates. The total costs at 1988-prices, including transmission line from Mbahu to Lichinga, is estimated at US $ 19.1 mill. (NOK 126 mill.), of which US $ 12.6 mill (NOK 83.2 mill.) are foreign currency costs. This implies an investment cost of NOK 62,000 per KW of installed capacity and NOK 11 per KWh of average annual energy production. The latter of these figures is, due to a higher firm power production, lower than the corresponding actual figure for the Lichinga hydropower plant. On the other hand, the former figure is almost 60% higher than the corresponding actual figure for Lichinga, which however, relates to the price level in 1981-83.

Again, professional services (to be carried out by Norconsult) account for a rather high amount of US $ 3.745 mill. (NOK 24.7 mill.), corresponding to 20% of total project costs and 30% of total foreign currency costs. Hydropower projects in the size order of Mbahu would benefit considerably if the costs of professional services could be reduced.

Assuming a discount rate of 10% Norconsult found that the power cost at the 1988-price level including costs of transmission line would be US c 32.8 per KWh, equivalent to NOK 2.16 per KWh.

NVE has estimated the cost of electricity from Mbahu delivered at the power station (i.e. excluding cost of transmission lines and other installations external to the power plant). Their calculation show that the assumed discount rate affects the result very much:

Discount rate	Power cost NOK/KWh	US c/KWH*
3%	0.65	9.85
7%	1.11	16.80
15%	2.17	32.90

* Assuming 1 US $ = NOK 6.60. Source: NVE, December 1989.

The only realistic alternative to hydroelectricity from Mbahu is diesel-generated electricity. Norconsult has estimated that when assuming a conversion factor of 1 litre diesel = 3 KWh and "normal" operation and maintenance costs (3% of investment costs) the cost of diesel-generated electricity would be US c 20.4 (NOK 1.35) at an assumed load factor of 50% and a discount rate of 10%.

However, the assumption of a conversion factor of 1 litre diesel = 3 KWh implies that the diesel plant is well adjusted, and uses fuel quite optimally. Experience shows that this is frequently fuel quite optimally. Experience shows that this is frequently not the case in countries such as Mozambique where lack of spare parts for diesel generators is endemic, due to foreign exchange constraints. If we assume a conversion factor of 1 litre of diesel = 1.5 KWh, then the cost of diesel-generated electricity will increase to about US c 30.50 (NOK 2.00) per KWh.

The figures presented above show that hydro-electricity from Mbahu competes quite well in terms of costs with diesel-generated electricity when we assume a discount rate of not more than 7%. It should also be kept in mind that the foreign exchange share of the costs of diesel-generated electricity is far higher than for hydropower. Compared to the diesel-alternative the development of hydropower implies effective saving of scarce foreign exchange. With the severe foreign exchange constraints Mozambique is now facing, project costs should be calculated with a "shadow price" on foreign exchange. In that case diesel-generated electricity would loose its cost advantage compared to hydropower also at discount rates considerably higher than 7%.

We have not made any attempt to scrutinise the assumptions underlying Norconsult's cost estimates. But we find that Mbahu is a rather expensive project. On the other hand, we have to conclude that mainly because of its foreign exchange implications and due to low reliability, diesel-generated electricity cannot be considered as a realistic alternative to electricity production at Mbahu in the foreseeable future.

1.7 Summary and conclusion

The hydropower station at Lichinga was initiated at the time when the diesel shortages were already affecting the supply of thermally generated electricity to the provincial capital. It was a necessary investment to ensure the survival of the existing social and economic infrastructure.

The growth in the number of consumers clearly indicates that there is a demand for electricity in rural towns. At the moment, there is a suppressed demand because the power stations do not operate at full capacity, mainly due to shortages of diesel fuel. Currently, about 40 per cent of the power is used for lighting and this is to be encouraged as it has multiplier effects. Well-lit streets and buildings help the security situation as well as providing households with illumination at night - this represents improved social conditions.

Lichinga is no low-cost project in terms of investment per unit of installed capacity. However, there was no cost overrun in project implementation. Moreover, the Lichinga hydropower project saves foreign exchange compared to the alternative of thermal power production.

The full potential of the project to bring about socio-economic changes is hampered because the project is not able to provide firm power throughout the year and because it cannot be backed up by thermal power, mainly due to diesel shortages.

The current economic and security situation in the country prevents the full realisation of the potential of rural electrification. Production of raw materials has fallen drastically.

The one disturbing long term effect of rural electrification in Lichinga is that it is not designed to enable substitution of domestic fuel sources such as charcoal and fuelwood.

Women are benefitting from rural electrification. For the majority this takes the form of labour saving devices, such as the maize mill, lighting in schools and improved health services.

Mbahu is a rather expensive project. On the other hand, we have to conclude that mainly because of its foreign exchange implications and due to low reliability, diesel-generated electricity cannot, in the foreseeable future, be considered as a realistic alternative to electricity production at Mbahu.