Distr.
LIMITED

E/ESCWA/TCD/1996/10
16 September 1996
ORIGINAL: ENGLISH

UNITED NATIONS
ECONOMIC AND SOCIAL COUNCIL

Economic and Social Commission for Western Asia

Report on Mission to the Republic of Yemen

(During the period 15-23 July 1996)

Prepared by

Mahmoud Saleh
Regional Adviser on Energy

The views expressed in this report are those of the author and do not necessarily reflect those of the United Nations Economic and Social Commission for Western Asia.

96-0322

TABLE OF CONTENTS

ANNEXES

INTRODUCTION

The Public Electricity Corporation (PEC) of the Republic of Yemen requested the services of Mahmoud A. Saleh ESCWA Regional Adviser on Energy to prepare an outline of a Master Plan for the electric power sector in Yemen.

The Regional Adviser undertook this mission during the period 15 - 23 July 1995.

ACTIVITIES

1. The Regional Adviser held several meetings with the Senior officials and experts (Annex I) of the PEC to discuss the Terms of Reference of the mission, and getting acquainted with the previous studies prepared by the PEC and other consultants. It was agreed that the Adviser will prepare a proposal of the Terms of Reference (TOR) of a Master Plan for the Electric Power Sector, based on the information which will be made available to the Adviser. This TOR will be a part of the submission of the PEC to the funding agencies requesting assistance in financing the preparation of the Master Plan.

2. After the preliminary discussions with the PEC experts and after reviewing the reports and studies which were made available, the Adviser prepared "Notes for Discussions" (Annex II). These notes were discussed with the Managing Director of PEC, the Deputy Managing Director for Planning and Projects and the Director General of Planning, who agreed on the issues raised by the Adviser and they requested the Adviser to proceed with the preparation of the TOR of the Master Plan.

3. The Regional Adviser, after returning back to the office, prepared the attached TOR (Annex III).

4. It is worth mentioning that there are three approaches to prepare the MP, namely:

(a) The MP will be prepared by the PEC staff with the assistance of consulting experts from outside the country as needed.
(b) The MP will be prepared jointly between the PEC and a consultancy firm.
(c) The MP will be prepared totally by a consultancy firm.

The adviser is in favour of the alternative (a) if possible, otherwise the alternative (b) could be adopted. The Adviser, believes that the alternative (c) should be excluded, since it will deprive the PEC staff from gaining experience in preparing such type of studies. In addition, the Adviser believes that without the full involvement of the national experts in this assignment, the foreign consultants, whatever may be their experience and knowledge, could not prepare, a Master Plan which matches with the cultural and social structures of the Yemeni society.

5. The Adviser visited the UNDP office in Sana'a and held a meeting with the Assistant Resident Representative and the National Officers. The Adviser briefed the Meeting on the mission. The Assistant Resident Representative explained the priority areas of UNDP with particular emphasis on the Community Development, Human Development and Environmental Issues. He, also, explained, that the UNDP is interested in the promotion of utilization of renewable sources of energy for rural and remote areas as means for community development, and environmental protection. The Adviser explained that the Biogas projects implemented in Southern part of Yemen Republic are in line with the UNDP priorities. The Assistant Resident Representative showed great interest in these activities and requested the adviser to send the published report concerning the subject. The Adviser -returning back to his office- sent the required documents.

ACKNOWLEDGEMENT

The Adviser would like to express his deep appreciation to the PEC officials for their fruitful discussions, help and provision of the reports and information.

The Adviser would like also to thank the UNDP staff for the assistance before and during the mission.

ANNEX I

LIST OF OFFICIALS CONTACTED

LIST OF OFFICIALS CONTACTED

PEC

1.	Eng. Ahmed Hassan Al-Aini	Managing Director
2.	Eng. Abdul Moati Al-Jonaid	Deputy Managing Director for Planning and Projects
3.	Eng. Salem Ba Hakim	Deputy Managing Director for Technical Affairs
4.	Mr. Fadli Al-Akwa'a	Adviser to the Minister of Electricity and Water
5.	Eng. Ali Mahmoud Abdul Hamid	Director General for Projects
6.	Eng. Ahmed Abbas Al-Wajih	Director General for Studies and Designs
7.	Eng. Fouad Hammoud Al-Kousi	Director of Central Technical Dept in Sana'a
8.	Eng. Ali Eid Al-Kassem	Central Technical Dept
9.	Eng. Mohammed Ali Salem	Computer Dept

UNDP

10.	Mr. Serge D. Elie	Assistant Resident Representative
11.	Mr. Moustapha Al-Mokhdar	National Officer

ANNEX II

NOTES FOR DISCUSSION

ISSUES TO BE TAKEN INTO CONSIDERATION DURING THE PREPARATION OF THE OUTLINE OF THE MASTER PLAN (MP)

(20 July 1996)

ISSUES TO BE TAKEN INTO CONSIDERATION DURING THE PREPARATION OF THE OUTLINE OF THE MASTER PLAN (MP)

I- Rationale/Justification

Three major events took place during the last decade, that have direct implications on the electric power sector. The previously prepared master plan - if any - should be revised or a new master plan should be prepared to accommodate the implications of these major events, namely:

1. The unity of YAR and PDRY in May 1990 to form the Yemen Republic.
2. The discovery of reasonable oil and gas reserves in both the Northern and Southern parts of the country during the eighties.
3. The trend of the Government of Yemen towards more involvement of the private investment (local and/or foreign) in the electric power sector, particularly in generation (BOO, BOT etc.) and may be in high voltage transmission.

II- Special Considerations

During the preparation of the Master Plan for the electric power sector the following should be taken into account:

1. The MP should cover the whole country, including those governorates which are to be connected to the national grid and those which may not be connected to the national grid due to their remoteness.

2. The MP should include an emergency plan to upgrade the generation and transmission facilities in the load centers which are facing or will face in the near future a shortage in the electric power supply such as Sana'a and Aden cities and the Governorate of Hadramout, in addition to the long term plan for the whole electric power sector.

3. The MP should be prepared in such a way that its implementation will be in phases, each phase is an entity by itself, and at the same time it represents a part of the whole integrated MP.

4. The MP should include a study on the restructuring of the existing institutions working in the field of electric power in order to re-orient such institutions to cope with the new realities including Rural Electrification.

5. The MP should consider the modalities for simultaneous operation of the privately owned power facilities, and those owned by the government.

6. The MP should emphasize the importance of capacity building and should propose plans for upgrading the training facilities, and also propose training programmes to upgrade the skills of the local manpower in various areas relevant to electric power.

7. The MP should include a study on the establishment of a data-base for the electric power sector, to create an institutional memory for this sector.

8. It is advisable that the MP should be prepared by a team of local experts from the PEC and other relevant planning institutions, assisted by a group of experts from outside the country, as needed, or at least the local staff should be involved -to the maximum possible extent- in the preparation of the MP.

9. Before preparing the MP, all previous studies undertaken by various consultants during the last ten years for the Northern and Southern parts of the country, should be carefully reviewed.

10. The MP should stress the Environmental Impact Assessment studies for each project.

11. During the preparation of MP full account should be taken of the socio-economic development plans of the country.

12. One of the ultimate objectives of the MP should be, the establishment of a unified electric power grid interconnecting all governorates of Yemen. The techno-economic feasibility of interconnecting the remote governorates to the unified national grid should be examined. If it does not prove to be feasible, individual plans for such governorates should be prepared on the basis of isolated grids. Also, the possibility of interconnecting the Yemen national grid to the planned El-Mashreq grid, should be examined.

13. The MP should stress the reliance on the utilization of the available energy resources in the country, especially the natural gas, for electric power generation.

14. The time horizon of the MP is proposed to be 15 - 20 years.

ANNEX III

TERMS OF REFERENCE
FOR
PREPARATION OF MASTER PLAN
FOR THE ELECTRIC POWER SECTOR
IN THE YEMEN REPUBLIC

TERMS OF REFERENCE
FOR
PREPARATION OF MASTER PLAN
FOR THE ELECTRIC POWER SECTOR
IN THE YEMEN REPUBLIC

A. INTRODUCTION

One of the major tasks that Yemen Republic (YR) face today is to ensure reliable and affordable supplies of electric power for the whole country. Ready access to electricity for all households has become one of the main targets of the government of YR. Providing electricity to all communities and reducing interruptions in electric power supply to existing users within 5 - 7 years period are legitimate demands of the people and endorsed by the political leadership.

The Power Electric Corporation (PEC) of the YR decided, as the Governmental body responsible for managing and operating the power sector, to prepare a Master Plan (MP) for this sector. The major objectives of the MP are to:

(a) ensure reliable and affordable electric power supply for urban areas of the whole country within a time period of 5 - 7 years;

(b) rely, as much as possible, on the utilization of the available energy resources in the country, particularly natural gas, for electric power generation;

(c) cover the whole country with an interconnected power grid within a time period of 15 years;

(d) establish a unified electric power grid interconnecting all governorates of Yemen, and to examine the techno-economic feasibility of interconnecting the remote governorates to the unified national grid. If it does not prove to be feasible, individual plans for such governorates should be prepared on the basis of isolated grids;

(e) prepare for the possibility of interconnecting the Yemen national grid with the planned El-Mashreq unified electric power grid, from one side with the Sultanate of Oman and from the other side with Saudi Arabia;

(f) provide the rural and remote communities with electric power from local supplies installed in these communities and relying, as much as possible, on the local energy resources such as renewable (solar, wind, biomass, ... etc) energy resources.

B. BACKGROUND

By the early 1960's electricity in the northern part of Yemen (former Yemen Arab Republic YAR) was being produced in the main cities on a small scale by government agencies and individual producers. The source of this electricity was small diesel-generator sets. Some of the private producers supplied their own homes and those of their immediate neighbours. These small generating and distribution schemes were gradually combined, and in 1963 the General Electricity Company of Sana'a was established as an independent company owned by both the Government and private shareholders. Similarly, the Taiz Electric Company was established in the same year. Two years later, in 1965 the Hodeidah Electricity and Water Company was established as a wholly owned subsidiary of Yemen National Bank. These three companies developed along completely independent lines.

In 1975, the government of Yemen established the Yemen General Electricity Corporation (YGEC), with the former three companies as its nucleus. The YGEC was entrusted with the generation and distribution of electricity to the three main cities of Sana'a, Hodaidah and Taiz, as well as to almost thirty other towns and rural centers. Although the YGEC was granted sole responsibility for generating and distributing electrical power, small scale generation for their own use was permitted with the license form the ministry in charge. A similar development took place in the Southern Part of Yemen (former People Democratic Republic of Yemen, PDRY) which ended up by having the Public Corporation for Electric Power, (PCEP) entrusted with the generation, transmission and distribution of electric power in PDRY. This situation continued until 1990, when a major event took place, that is **the unity of YAR and PDRY to form the Yemen Republic**.

As a result, the YGEC and PCEP were amalgamated together to form the present Public Electricity Corporation (PEC) which is the governmental body entrusted with the generation, transmission and distribution of electric power for the whole Yemen Republic.

Another major even that took place during the eighties is **the discovery of reasonable oil and gas reserves** in both the Northern and Southern parts of the Yemen Republic. This led to the adoption of policy directives to utilize, as much as possible, **the natural gas as the main fuel for the electric power plants** which will be built in the coming years.

In addition, needless to say that the electric power sector is highly capital intensive, and substantial investment will be required to meet the rapidly rising demand for electric power. Therefore, the government is turning to innovative investment schemes, more rational electricity pricing and more efficient supply and demand management.

This necessitates **more involvement of the private investment** (local and/or foreign) **in the electric power sector,** particularly, in generation using the Build - Operate - Own (BOO) and/or Build - Operate - Transfer (BOT) arrangements and may be also in high voltage transmission. In addition, **a restructuring process of PEC** is to be undertaken, so that the PEC can meet the new realities and challenges.

C. SPECIAL CONSIDERATIONS

During the preparation of the MP for the Electric Power Sector the following should be taken into account:

1. The time horizon of the MP is proposed to be up to year 2015.

2. During the preparation of the MP full account of the socio-economic development plans of the country should be taken into consideration.

3. Before preparing the MP, all previous studies undertaken by various consultants for the Northern and Southern parts of the country, should be carefully reviewed. These studies include, but not limited to:

   (a) "Urban Distribution Upgrading and Expansion Study", prepared by Kennedy & Donkin Power Systems (KDPS), 1990.

   (b) Distribution Investment Programme Report, prepared by KDPS, 1989/1990.

   (c) Eastern Power Grid Study, prepared by KDPS, 1989/1990.

   (d) Load Forecasts, Generation, Transmission and Distribution Studies, prepared by KDPS, 1977.

   (e) YAR/PDRY Power Link Study, prepared by KDPS, 1988.

   (f) Yemen Arab Republic Energy Strategy Review, prepared by the World Bank, 1990.

   (g) Gas Utilization Study prepared by Gasunie Engineering B.V., 1988 and updated in 1992.

   (h) Power III and Power IV Electrification Project, prepared by Lahemyer International 1984 and 1986.

   (i) Load forecast 1992 - 2010 (the Southern System), prepared by ...., 1992.

   (j) Power V, Rural Electrification Feasibility Studies, prepared by NRECA International Inc., 1987.

   (k) Feasibility study for Gas Turbine and Transmission Facilities, prepared by Overseas Bechtel incorporated, 1993

4. The MP should cover the whole country, including those areas which are to be connected to the national power grid, and those which may not be connected to the national grid due to their remoteness.

5. The MP should be prepared in such a way that its implementation will be in phases, each phase is an entity by itself, and at the same time it represents a part of the whole integrated MP. The MP should include an emergency plan to upgrade the generation and transmission facilities in the load centers which are facing or will face in the near future a shortage in the electric power supply such as Sana'a and Aden cities and the Governorate of Hadramout.

6. The MP should include a study on the restructuring of the existing institutions working in the field of electric power in order to re-orient such institutions to cope with the new realities including Rural Electrification.

7. The MP should emphasize the importance of capacity building and should propose plans for upgrading the training facilities, and also propose training programmes to upgrade the skills of the local manpower in various areas relevant to electric power.

8. The MP should include a study on the establishment of a data-base for the electric power sector, to create an institutional memory for this sector.

9. The MP should consider the modalities for simultaneous operation of the privately owned power facilities, and those owned by the government.

10. The MP should stress the Environmental Impact Assessment studies for each project.

D. Scope Of Work

As mentioned earlier, the implementation of the MP will be in phases. The proposed time schedule of implementation of the different phases is shown in the attached bar chart. A summary of the scope of work for each phase is given in this chapter.

Phase I: Load Forecast Study:

The load forecast study is expected to include:

1. Review of load forecasts previously made by the local corporations PEC,

YGEC and PCEP, or other consultants.

2. Existing and historic electric energy production and consumption by consumer category including details, to the best of the available information, of the number of consumers, daily load curves, seasonal and annual demand variation, etc...

3. Details of existing substations and feeder loads.

4. Existing level of private generation and the potential, if any, for supplying their loads from the public power network.

5. Economic and demographic data including, but not limited to, size of populations and the projections for its growth, number of households and the projected increase in this number, and data on the most important sectors of the economy and the expected future developments in projects which consume substantial amount of electrical energy.

6. Existing end uses of electricity and the effects of load shedding and forced outages on the typical consumers.

7. Analysis and evaluation of the collected data.

8. Three scenarios of electrical load growth forecast (base, high and low growth scenarios) for the different regions and for the whole country until the year 2015.

Phase II: Emergency Plan:

The electric power supply to the four major load centers in YR, namely: Sana'a, Aden Taiz and Hodeidah and the Governorate of Hadramout is already inadequately secure and potentially overloaded. Therefore, an emergency action is immediately required to satisfy the power demand for these areas, and to minimize, as possible, the incidence of load shedding and the undervoltage problems. The question of supply security in these areas should be carefully examined and appropriate solutions should be proposed.

Phase III: Alternative Generation Plans:

The scope of work for this phase will include the formulation, analysis and evaluation of different generation options to provide safe and adequate electric power supply to meet the load forecasts of aggregate and disaggregate MW peak demands and energy requirements over the period to 2015. This study should include, but not limited to, the following items:

1. **Assessment of the existing generation plants:**

The existing power plants are to be evaluated regarding their age and

conditions of each unit, spare parts availability, fuel and lubricating oil consumption, operation and maintenance costs, etc.., in order to assess the future output capability, the needs -if any- for rehabilitation, and the most suitable date of retiring for each unit.

2. Future generation options:

Based on the results of the load forecast study, the installed capacity needed to meet the power demand up to 2015 is determined. Then the geographical distribution and the timing of operation of the power plants needed up to 2015 could be determined.
Also, the selection of power plant types could be done based on a comparative techno-economic analysis of the different technology options including:

(a) oil and/or gas fired steam power plant;
(b) dual purpose steam turbine plant for power generation and water desalination;
(c) oil and/or gas fired simple cycle gas turbine plant;
(d) oil and/or gas fired combined cycle plant.

3. Site selection of power plants:

There is a wealth of information from the previous studies on the possible locations for the future power stations. These information are to be examined carefully on the basis of:

(a) the location of the power station relative to the load centers;
(b) suitability for and cost of fuel delivery;
(c) transmission re-enforcement requirements;
(d) ease of access for getting major equipment to the site and for operating personnel;
(e) ability to meet water requirements at reasonable cost;
(f) geology and topography of the site;
(g) land availability and cost.

4. Least cost generation scheme:

A least cost expansion scheme for generation is to be prepared. Initially it may include all reasonable alternatives. Then, it may be possible to exclude some of the options by screening analysis. The capital cost estimates of the candidate power plants which pass the screening analysis are to be prepared. These will include the capital costs of the major mechanical and electrical plant items, the civil work, the extra high voltage (EHV) substation, connections to the transmission system and the fuel transportation costs.

Phase IV: Alternative Transmission Plans:

1. Alternative transmission plans will be prepared for each generic generation plan to the year 2015 to meet the load forecast for bulk supply points.

2. The technical and economic advantages and disadvantages of the different alternatives will be compared. In particular the following will be evaluated:

   (a) Assess the Loss of Load Probability (LOLP) for each alternative system programme;
   (b) Rank the alternatives according to their net present value over an appropriate range of discount rates;
   (c) Apply appropriate sensitivity analysis (capital costs, fuel costs).

3. By means of load flow analysis for each transmission option, the cost of system losses will be included in the economic and financial analysis using estimated Long Run Marginal Costs (LMRC).

4. A least cost transmission plan will be established for each generation plan and costings produced for input to the economic and financial analysis.

5. The recommended generation and transmission alternative will be supported by system studies such as short circuit transient stability analyses that may be required to prove the feasibility of the recommended alternative using appropriate and declared system planning criteria for normal and contingency operation at each stage of development of the recommended scheme.

6. For the recommended generation and transmission optimal scheme, voltage levels and conductor sizes shall be determined for proposed transmission lines.

7. Regarding the supply security criteria, standard levels for supply reliability based on a loss of load probability (LOLP) criteria are to be proposed for the different types of consumers.

Phase V: Interconnection With The Neighbouring Gulf Countries:

In the mid 1980's the Gulf Cooperation Council (GCC) initiated a study on the integration of the electric systems of the GCC member states, namely: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates. Several possible interconnection schemes are proposed to provide reserve sharing, more economic and flexible operation of the networks, and possibility of assistance from neighbouring systems to cope with unforeseen construction delays and unexpected load growth. Up till the present time, no action has been taken on the implementation of the GCC interconnection. However, it is expected within the coming few years, that GCC countries realize the importance of this interconnection and will allocate the necessary funds to implement it.

Yemen Republic should be ready to interconnect its unified electric network (which

is expected to be completed by 2015) to the GCC interconnected network. It is expected that the MP will include a study on the techno-economic aspects of interconnecting the Yemen grid with the neighbouring Gulf Countries, namely Saudi Arabia and the Sultanate of Oman.

In addition, the modalities of cooperation and the allocation of responsibilities between Yemen and these two countries in this respect should be examined.

Phase VI: Rural Electrification Programme:

A rural electrification strategy is to be formulated aiming at the development and introduction of less costly alternative power supply options to rural and remote communities where the majority of Yemeni population live. Not all these communities could have access to the electric power grid, due to the high cost of grid extension resulting from the long distance and the scattered demand of power. However, despite the high cost, social and political pressures for grid extension will remain. The second option is the use of privately owned diesel generation. This option is widely used in Yemen inspite of the high cost of fuel transportation, the non-accessibility of these areas during certain periods of the year, the high cost of diesel generator sets and the scarcity of repair and maintenance skills. In addition, the capacities of those diesel units are not properly sized to demand, equipment operation is sub-optimal, proper safety and maintenance procedure are often lacking, and generator output is probably highly underutilized. Inspite of all this, small diesel-generator units will likely continue to dominate electric power supply for rural and remote areas. Therefore, it is important to evaluate the potential for more efficient operation of this option in Yemeni rural and remote areas and to develop mechanisms to improve the service and reduce the costs of small private generators. The third option is to introduce renewable (solar photovoltaic and/or wind - electric) energy technologies to supply electric power to rural and remote areas in Yemen. However, this option is site specific and needs meteorological data as solar insolation and wind speeds for each site.

A thorough evaluation of costs and benefits is to be undertaken of each option, namely: grid extension, private diesel power generation, utilization of solar photovoltaic, wind powered generators or hybrid photovoltaic-diesel. Based on the results of this evaluation, a detailed **rural electrification programme** is to be developed. The implementation of this programme will extend over the whole period for which the Master Plan is prepared i.e., up to year 2015.

Phase VII: Capacity Building:

1. Strengthening PEC:

The current institutional set-up which is mainly the PEC, is largely the amalgamation of the institutions that existed in YAR (YGEC) and PDRY (PCEP) prior to the formation of the Republic of Yemen.
Each of these institutions YGEC and PCEP had its own mandate, responsibilities, organizational structure and specific features irrespective of their different geographical coverage.

At present the situation is different and also a new element is introduced, that is the new policy of the government to involve the private sector (local and/or foreign) more and more in large scale power generation using BOO and/or BOT arrangements and in high voltage power transmission on leased line basis. This necessitates reviewing the present organizational structure of PEC and identifying the emerging needs of the power sector emanating from the new realities. Therefore a restructuring plan of PEC is to be proposed within the MP, which may include but not limited to:

(a) Review of the present organizational structure of PEC;
(b) Identification of the emerging needs of the power sector;
(c) Proposal of a new organizational structure of PEC specifying the mandate of PEC, the responsibilities and the manpower and their qualifications for each department, taking into consideration to utilize the existing personnel as maximum as possible after retraining and up-grading the skills as needed.

2. Training:

A proposal for a comprehensive training programme is to be prepared. The programme objective is to retrain and upgrade the skills of PEC staff to enable them to ultimately acquire all necessary skills needed to run PEC. In addition to the classical training disciplines on operation, maintenance and repair of power plants, transmission lines, substations, distribution systems, etc... new training courses should be introduced such as information technology, negotiations and preparation of agreements and contracts with private investors; rural electrification etc...
The training programme is to be continuous and flexible to cope with any arising future needs.

3. Information Center:

A proposal of establishing an **information center** within the PEC is to be prepared. This proposal should include the equipment, the manpower and space requirements for this center, in addition to the type of training to enable the staff to run the center. It is expected that the center will have a Geographic Information System (GIS) indicating the locations of all power plants, substations, transmission line routes, distribution network etc.... In addition all the studies previously prepared, or ongoing, signed agreements and contracts should be stored in the computer. Automation of the administrative services, (personnel, budget, payroll, etc...) and follow up of ongoing projects should be part of responsibilities of the information center.

PROPOSED IMPLEMENTATION SCHEDULE FOR THE DIFFERENT PHASES OF THE MP