IAEA-TECDOC-917

Potential for nuclear desalination as a source of low cost potable water in North Africa

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The originating Section of this publication in the IAEA was

Nuclear Power Technology Development Section
International Atomic Energy Agency
Wagramerstrasse 5
P O Box 100
A-1400 Vienna, Austria

POTENTIAL FOR NUCLEAR DESALINATION AS A SOURCE
OF LOW COST POTABLE WATER IN NORTH AFRICA
IAEA, VIENNA, 1996
IAEA-TECDOC-917
ISSN 1011-4289

Printed by the IAEA in Austria
November 1996

FOREWORD

At the 1989 General Conference of the IAEA, renewed interest in the potential of nuclear reactors for seawater desalination was expressed by some Member States, and a General Conference Resolution of that year requested the Director General to assess the technical and economic potential of nuclear reactors for seawater desalination in the light of experience gained during the previous decade.

Based on the limited regional water resources and in recognizing the possible role of nuclear energy in seawater desalination, the five North African Countries (NACs): Algeria, Egypt, Libya, Morocco and Tunisia submitted a request to the IAEA in 1990 for assistance in carrying out a feasibility study on the use of nuclear energy for seawater desalination in some pre-selected sites in these countries to cover their medium- and long-term needs for economical potable water production.

The present report has been prepared and is presented to the NACs in response to their request. It contains an assessment of the regional specific aspects, the available technical options with respect to desalination processes and energy sources, the cost evaluation of various technical options for the production of desalted water, as well as the financial constraints and options, and finally the necessary steps needed to ensure the successful implementation of a nuclear desalination programme.

The report also complements other work of the IAEA in the field of nuclear desalination, carried out in response to various resolutions of the IAEA General Conferences since 1989, namely: "Use of Nuclear Reactors for Seawater Desalination", IAEA-TECDOC-574 (1990) and "Technical and Economic Evaluation of Potable Water Production through Desalination of Seawater by using Nuclear Energy and Other Means", IAEA-TECDOC-666 (1992).

It is hoped that the results of the present study will provide valuable information to other interested countries and to the IAEA's future efforts in the field of utilization of nuclear energy for seawater desalination, such as the Options Identification Programme and the Nuclear Desalination Demonstration Facility.

Appreciation is expressed for their valuable contributions to all those experts who participated in the preparation of this report and also to the Members States for their support.

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1. EXECUTIVE SUMMARY

1. Introduction

The adequate supply of potable water is a major problem in the world and especially in the North African Region (NAR). A comprehensive study carried out by the United Nations Environmental Programme (The Blue Plan: Future of the Mediterranean Basin Environment Development 2000-2025) concluded that, between 1985 and 2025, the urban water consumption in the countries south and east of the Mediterranean basin might increase by a factor of about 4. This is in contrast to the increase in the countries north of the basin, which might be increased by a factor of 1.5 only.

In view of their limited water resources and the possible role of nuclear energy in seawater desalination, five North African Countries (NACs): Algeria, Egypt, Libyan Arab Jamahiriya, Morocco and Tunisia submitted a request to the IAEA for assistance in carrying out a feasibility study on seawater desalination by using nuclear energy at selected sites.

A preparatory meeting was held to define an action plan, and several regional meetings were held to review the progress of the study. In addition several expert missions were also carried out to perform specific tasks. This study has been performed in the period 1991-1994, and the present report documents the results obtained. The report addresses four major areas, namely: regional specific aspects, available technical options, economic and financial aspects, and prospects.

2. General Aspects of The North African Countries

All five NACs lie within the temperate zone, and the bioclimate varies from arid to extremely arid. Rainfall in most parts of the NACs is marginal and insufficient to cover current demand of fresh water. Drought years are common. The North African population was about 118 millions in 1990 (nearly 3 times the population in 1950) and is expected to reach 220 millions in the year 2025.

In the past 30 years a significant expansion has also occurred in industry, mining and tourism. The average per capita Gross Domestic Product (GDP) in the region increased from US $300 in 1960 to US $809 in 1985, based on 1975 year US $ value, corresponding to an average annual growth rate of 4%. Positive future growth rates of the GDP/capita are expected because of expansion of industrialization. As a result, there will be an increasing need for potable water over and above what will be needed for the expanded population.

3. Regional Water Supply and Demand

The largest source of surface water in the region is the River Nile which is, however, only of significance for Egypt. Surface water in the region include smaller rivers in Algeria, Morocco, and Tunisia and rain water intercepted by dams or connected cisterns. These, however, are limited and/or polluted due to uncontrolled urban growth.

Available data give only a partial and somewhat contradictory description of the water supply and demand picture in the NACs. Nevertheless, it is evident that the water supply to the majority of the large cities in the region does not comply with World Health Organization (WHO) recommendations for potable water, affecting the level of living standard and especially increasing health problems. Most of the NACs intend to use the WHO recommendations for potable water standards. These recommendations can be met by commercially available seawater desalination processes including multi-stage flash (MSF), multi-effect distillation (MED) and reverse osmosis (RO).

Groundwater resources play an important role in providing fresh water in the NAR, particularly in places where surface water resources are very limited such as Libyan Arab Jamahiriya. Most of these resources are fossil and available at great depth. In the coastal areas, large scale extractions have led to a sharp decline in water levels followed by seawater intrusion. Overextraction and pollution have reduced the availability of potable water drastically. The study estimates that, by the year 2025, the overall regional water deficit could be as high as 40 million m^3/day. Seawater desalination could play an important role in closing this gap.

4. Regional Energy Supply and Demand

Water desalination requires energy. Heat and electricity are the two forms of energy used in desalination processes. A survey of regional primary energy resources was carried out based on data presented by the participating countries, and complemented by data available from international organizations.

The analysis of the regional energy resources reveals that the only significant indigenous primary energy resources in the region are crude oil, natural gas, and hydraulic energy. Crude oil and natural gas are expected to be depleted in the next century unless new discoveries are made. Hydraulic energy, used solely to produce electricity, is nearly fully utilized. Therefore, nuclear power could play an important role in meeting the expanding regional needs for heat and electricity.

For the cases where a nuclear reactor produces electricity or where it operates in the cogeneration mode, supplying electric power to the grid and heat for the desalination plant (MED or MSF), the plant size would be practically limited by the grid size. Therefore, an analysis of future electricity demand and supply is essential.

A survey of regional electricity generation over the period 1970 to 1990 indicated that the electricity generation increased form 12 TW·h in 1970 to 80 TW·h in 1990 with an average annual growth rate of about 10%. The total installed electricity generating capacity in the NACs in 1990 was 20 GW(e). Projections of electricity demand in the NACs for the period 1990-2025 indicate that the demand in the year 2000 will be almost twice the 1990 electricity consumption. By the year 2010, it will be tripled, and by the year 2025 the electricity consumption will be almost six times the 1990 consumption. The corresponding required installed capacity in the year 2025 would be more than 100 GW(e), which is more than 5 times the 1990 installed capacity and corresponds to an average annual growth rate of about 5%.

5. Representative Sites

Early in the study, in 1991, a number of sites in need of potable water were identified by the individual countries, outside the scope of the present study, with rough estimates of the required demand. Revised data became available in May 1994. However, the revised data have not been included in the cost comparison which was already under way.

Eleven reference sites for nuclear desalination plants were identified. Based on the range of needed desalination capacities for the year 2005, as reported in 1991, and the site locations, five sites, one in each country, were chosen for the economic assessment. These were: 24 000 m^3/d (Laayoune, Morocco), 60 000 m^3/d (Zarzis, Tunisia), 120 000 m^3/d (Oran, Algeria), 240 000 m^3/d (El-Dabaa, Egypt) and 720 000 m^3/d (Tripoli, Libya).

6. Desalination Processes

Numerous processes have been proposed for the desalination of seawater. However, few of these have attained commercial status. The only suitable processes for large scale seawater desalination are the distillation processes such as MSF, and MED and the membrane separation processes such as RO. For smaller water demand, MED Vapour Compression (MED/VC) has also been successful. MSF and MED use heat as the energy source; RO and MED/VC use electricity as the energy source.

A preliminary economic evaluation within the present study indicated that under the assumptions applied, MSF water cost would be higher than MED or RO. Previous studies highlight that both MED and RO are expected to be the main seawater desalination process in the next two decades. Therefore, only RO, MED and the hybrid process MED/RO were considered in the present study.

7. Energy Sources

The competitiveness of nuclear power with alternative power generation is an important factor in nuclear power development. Hence, scanning of a wide range of energy sources is essential. However, because the focus in this report is on nuclear energy, investigation of other energy sources is confined to providing a gauge to the economic competitiveness of nuclear energy.

Most of the nuclear plants considered in this study are advanced small and medium size reactors, of which some are expected to be commercially available by the year 2005. The technical and economic data of the considered reactors were provided by vendors as a reply to an IAEA questionnaire for this purpose. No attempt has been made to assess this information in any way. These reactors are based on a variety of concepts: pressurized light water-cooled reactor (PWR), pressurized heavy water-cooled reactor (PHWR), high temperature gas-cooled reactor (HTGR), and liquid metal cooled reactor (LMCR). These designs also offer diverse applications: heat production only, dual purpose heat and electricity production, and electricity generation only.

8. Coupling of Desalination Plants with Nuclear Plants

There is no technical requirement for joint siting of an RO or MED/VC desalination plant and the electricity generating plant, although the study shows that there are economic benefits in doing so. When there is only an electrical connection with the desalination plant, there would be no risk of radioactive contamination reaching the potable water produced from the reactor primary circuit, and hence there would be no need for particular protection systems. For the MED process, joint siting of the heat source and the desalination plant is necessary. It is essential to eliminate the possibility of radioactive material penetrating into the desalination system. This is achieved through an additional heat transfer or isolation loop involving additional cost and energy.

In the economic assessment, a number of site specific power and water plant coupling cases have been identified for each of the selected sites. In order to accommodate grid stability, a conventional criterion was adopted, that is a single power unit could not be larger than 10-15% of the projected grid size. Because the number of possible combinations for each site is extremely large, only representative combinations that were judged to be most practical were selected.

9. Regional Desalination Experience

A total seawater and brackish water desalting capacity of about 900 000 m^3/day has been installed in the North African Region during the last 2 decades. Nearly 50% of this capacity are MSF plants for seawater desalination. The remainder are mainly RO and MED for brackish water and a small number of MED/TVC (thermal vapor compression) and MED/MVC (mechanical vapor compression) plants for seawater desalination. Unfortunately the number of plants running without important problems is relatively small. The main problems encountered are corrosion, scaling, fouling of RO-systems, component failures due to the fact that the local conditions have been neglected and, to a smaller extent, maintenance problems.

Most of the desalination plants in the Region, especially for large capacity, were custom-made. Hence, there was no common approach to facilitate training of personnel, operation and maintenance, to have access to spare parts and to transfer experience. In particular, the trained manpower for operation and maintenance in the NACs is relatively small and should be increased. Standardization of future desalination plants would facilitate a solution to these problems.

10. Survey of Regional Participation Capabilities

A major goal identified by the NACs is the achievement of eventual self-sufficiency in design, manufacturing, operation and maintenance of nuclear power and desalination plants. Therefore, a survey of local participation capabilities was carried out. A regional labour pool was identified, which could supply the manpower for a nuclear power and desalination programme.

Generally, the standard of education in high schools, technical institutes, and universities in the NACs is high. There are already qualified engineers available for nuclear power programme activities. No insurmountable problems are foreseen in providing an adequate skilled labour force for the construction of desalination plants or nuclear plants, provided that a high level of regional co-operation is maintained and that suppliers ensure that key supervisory personnel is available.

The general quality and quantity of professional training in the universities and specialized training centers seem adequate, although additional training related to the special requirements of a nuclear power and desalination programme will be necessary. There are many consulting firms in the region that provide basic engineering and other technical services. Some of these firms have participated in the construction of large desalination plants in the Gulf States.

Evaluation of national manufacturing capabilities with respect to nuclear power and desalination equipment was carried out in some NACs to various degrees of detail and sophistication. There are indications that important regional manufacturing capabilities exist. However, for the NACs to achieve the goal of self-sufficiency, adequate supply of trained manpower, additional and improved manufacturing facilities, financial resources and a strong NACs governments' commitment to a nuclear power programme are necessary.

11. Cost Comparison

To estimate the cost of power and water for the five selected sites, the same methodology was used as in the generic study carried out by the IAEA and published in 1992 (Technical and Economic Evaluation of Potable Water Production through Desalination of Seawater by using Nuclear Energy and Other Means, IAEA-TECDOC-666). The analysis in the generic study was carried out for representative sizes of nuclear reactors coupled with various desalination processes. A parametric approach was used for the reactor data based on pressurized water reactor data.

The present analysis is based on reactors selected on the basis of power outputs compatible with grid requirements and the availability of economic data supplied by the vendors. The water plant size has to match the site water demand independent of the power plant size. Numerous improvements and performance options were also added to the calculation methods in the present regional study.

The cost estimates of the various nuclear/desalination coupling schemes for the five reference sites were made in constant value January 1994 US $ and compared on a consistent basis with fossil fueled plants (steam power plants, gas turbines, combined cycles, diesel engines, and boilers) as well as solar ponds. Adjustments were made to the nuclear plant costs to reflect the additional costs anticipated for construction in the NACs. A reference oil price of US $15 per barrel, with 2% per year real escalation was used. Both oil price and nuclear fuel cost reflect current and projected market conditions. Sensitivity analyses were carried out to address uncertainties in interest rate, basic oil price and the escalation rate of the oil price.

The results of the economic evaluation indicated that, the levelized water costs for both fossil and nuclear fuels are comparable. The cost per cubic meter of desalted water ranged from US $0.70 to US $1.0 4 for fossil, and from US $0.73 to US $0.91 for nuclear, depending on the size of the plant. Water production costs with single purpose heat only plants were found to be substantially higher than with dual purpose (electricity and heat), or single purpose electricity only power plants. Lower interest rates tend to favour nuclear options.

Under the assumptions and coupling schemes utilized in the economic assessments, the use of nuclear energy for seawater desalination is competitive with fossil energy. However, early use of nuclear energy for both electricity generation and seawater desalination will extend the life of the depletable fossil fuel resources in the Region.

12. Financing

Financing nuclear power projects in NACs might be difficult. In particular, providing the foreign component of investment for a nuclear project in the NACs from international markets with the current approaches could be problematic. There are alternative financing approaches, such as BOT (build-operate and transfer), ECOs (expanded co-financing operations), countertrade arrangements and the "whole-to-coal" model. However, to date, no large nuclear power project in any country has been implemented using these new approaches.

NACs will have to depend on their own resources either individually or collectively. A relevant individual or national solution is the Alternative Energy Fund of Egypt. A collective regional solution could be the establishment of the Regional Drought Fund, which was proposed by Libya during the course of the present study.

13. Joint Regional Activities

Feasibility studies on seawater desalination through utilization of nuclear energy have been carried out on the national and regional levels. However, the implementation of such a project is new to all countries of the Region, therefore, a new co-operative approach might possibly be applied easier than in other fields where practices are already established, and where a change of attitude would be required.

The main areas where regional co-operation appears to have a special interest are legal framework, licensing and regulatory aspects, feasibility studies, manpower development, manufacturing, acquisition and financing, research and development. Developing regional capabilities and assuring an optimized local participation should be considered as a framework for all future projects. Optimizing local participation necessitates regional co-operation in various activities such as: site studies, feasibility studies, project management, design, engineering, manpower development and manufacturing.

14. Safety, Licensing and Environmental Aspects

The utilization of nuclear power and fossil fuel for electricity generation and/or for seawater desalination has an environmental impact even when all regulatory standards are met. In addition, the desalination plant may have an environmental impact associated with concentrate discharge. Thus, early in the project a detailed environmental impact analysis should be performed for the plant that is expected to be constructed and operated at the proposed site. Nuclear safety and environmental considerations in nuclear desalination are those arising from the use of nuclear reactors as energy sources. Nuclear safety and regulatory actions should be based on relevant IAEA safety documents, e.g. Safety Fundamentals, as well as NUSS documents such as Safety Series-50 and Safety Series-110.

In particular, it is vital that the design, operation and performance of an integrated nuclear desalination complex shall ensure the protection of product water against radioactive contamination.

Any safety assessment and review of a nuclear desalination plant might be undertaken in two stages. The first stage could be carried out in co-operation with the regulatory body of the country of origin (i.e. licensability in the vendors' home country). If required, the regulatory body of the country of origin may be reviewed with the assistance of the IAEA. The second stage could be carried out in co-operation with the IAEA based on its safety documents.

15. Implementation Programme

The introduction of nuclear energy in any country, particularly in developing countries is a long, complicated and challenging process. In order to launch a nuclear programme for the production of electricity and/or desalted water, several conditions have to be satisfied. These include: adequacy of the legal and regulatory infrastructure, of the electric grid, qualified manpower, industrial support, and financing.

16. Institutional Aspects

The introduction of nuclear energy for electricity generation and/or seawater desalination creates new infrastructure requirements and involves national and regional commitments on a long-term basis, with substantial manpower and financial resources. Regional co-ordination and co-operation can provide a framework within which the institutional and resource commitments can be shared.

The initiation and formulation of a nuclear desalination programme and the subsequent projects, requires from the institutional point of view adequate organizational structures for the management of required activities.

The creation of a North African Safety Advisory Group (NASAG) could facilitate the development of a common approach to safety and regulation in the Region. This might be facilitated by the fact that no nuclear power plants exist in the Region.

The NACs can obtain nuclear technology, nuclear reactors, nuclear fuel and materials and equipment from foreign suppliers only if they can provide adequate evidence of their exclusively peaceful uses. Other concerns regarding nuclear reactors, such as physical protection or third party liability, also need to be resolved through governmental commitments.

Experience shows that public and political acceptance of nuclear energy strongly depends on the perception of the risks incurred and the benefits obtained from using this energy source. To gain public acceptance for the utilization of nuclear energy in seawater desalination, the benefits of potable water production must be emphasized, and it must be demonstrated credibly that there is no risk of radioactive contamination of product water. A regional public acceptance committee should be created to undertake careful planning for public acceptance in co-operation with the mass media in the Region.

17. Conclusions and Recommendations

The increasing demand for both electricity and potable water in the NACs, combined with the depletion of energy resources, limited water resources, population growth and ambitious development plans, make it desirable to resort to alternative schemes for providing future electricity and water needs.

The use of nuclear energy as an alternative option to the use of fossil fuel for generating electricity and supplying energy for seawater desalination is technically feasible, and in general economically competitive for medium to large size units integrated into the electric grid systems within NACs.

Regarding the technical feasibility, there are no impediments to the use of nuclear reactors for the supply of energy to desalination plants. However, requirements due to the special characteristics of nuclear power, institutional issues have to be solved, in order to ensure proper project implementation and ultimately safe and reliable operation of the nuclear plant.

It has been found that some combinations of nuclear reactors and desalination systems are economically competitive with alternative sources within the framework of the input data used and assumptions adopted for the economic analysis. Although a preliminary conclusion on the competitiveness and viability of nuclear desalination can be reached at the feasibility study stage, the final decision on the investment could only be reached on the basis of responses to an invitation to tender. This will more closely define the costs of a first nuclear power project in the NACs and provide a firmer basis for comparison with alternative options.

No doubt, financing of the large investments involved constitutes a major constraint, in particular for those countries of the Region which have scarce capital resources. Financing, however, should be viable if adequate Governmental commitments and corresponding investment priority policies are adopted.

The present Regional Feasibility Study is a promising start to promote the sharing of efforts and ultimately also the benefits among the NACs. The results have been positive, in general, and the efforts have generated an increasing level of co-operation within the Region. A large number of issues have been identified, which should be addressed, on both regional and national basis, to capitalize on the work carried out to date. In this regard the following recommendations are made:

1. Establish a small group of multi-disciplinary NACs' experts to define the necessary steps and tasks, based on the results of the present study including their costs, needed to start a second phase of this study, namely "The Impact of Site Specific Aspects on the Use of Nuclear Power for Seawater Desalination". This second phase study would include, but not be limited to, the following:
    - Narrow down the number of reference sites, possibly to the three identified joint sites (or at least one of them).
    - Select the most promising systems from this study.
    - Ensure more reliable data for water demand and deficit.
    - Define the infrastructure requirements for fossil and nuclear options at the selected site(s).
    - Identify the scope of regional participation.

2. Establish a Regional Water Commission whose primary role would be to create, maintain and update a reliable regional data base on the existing fresh water resources, future plans for seawater desalination development, potable water supply, demand and deficit.

3. Acquire the necessary skills within the Region to develop modeling capabilities needed for analysis of various reactor/desalination systems.

4. Establish a North African Safety Advisory Group (NASAG) to give advice on nuclear safety issues related to nuclear desalination. NASAG could also set up the basic safety criteria for the Region, and review and harmonize existing legislative and regulatory framework in the Region.

5. Establish a Regional body to maintain and update a data base of manufacturing capabilities in the Region. A detailed and in depth regional study on the manufacturing capabilities should be the first task.

6. Consider the establishment of a Regional Drought Fund for the supply of the necessary funds, and the adoption of investment priority policies to carry out a "nuclear desalination" programme.

2. GENERAL ASPECTS OF THE NORTH AFRICAN COUNTRIES

2.1 GEOGRAPHY

The NAR consists mainly of the five NACs; Algeria, Egypt, Libyan Arab Jamahiriya, Morocco, and Tunisia, with an area of about 5.75 million square kilometers (including Sinai and Western Sahara). The Region (Figure 1) is bound by: the Mediterranean Sea in the North, the Red Sea in the East, the Atlantic Ocean in the West, and the Great Sahara Desert in the South. The NACs' coast line extends about 10,000 km along the southern coast of the Mediterranean Sea (5,600 km), the Red Sea coast (2,000 km) and the Atlantic Ocean coast (2,400 km). The NAR consists of three major terrain, namely:

(i) Nile Valley and Delta which accounts for 0.7% of the total area of the five NACs, but is inhabited by about 43% of the Regional population.

(ii) The Atlas Mountains which extend across Algeria, Morocco and Tunisia. The high Atlas Range is the highest and most impressive of the Atlas Mountains, rising over 3000 meters above sea level. Some peaks are nearly 4000 meters.

(iii) The Sahara Desert (Desertia) which covers more than 90% of Egypt and Libyan Arab Jamahiriya, about 85% of Algeria, and less than 50% of Morocco and Tunisia. The relief of the Sahara Desert is quite varied, ranging from the high dissected plateaus of the center to the marginal depressions or basins such as Qattara, Fezzan, Shatt El-Djerid and Taneznouf. Some parts of the Sahara plateau are distinguished with high altitudes over 3,000 meters, such as Tibesti in Libyan Arab Jamahiriya and Ahaggar in Algeria.

The most important feature of these countries is the common aridity (excluding the Mediterranean coast and the Atlas Ranges). The areas of greatest rainfall in the NAR are Seaward slopes of northern ranges such as Algiers and Constantine in Algeria and Shahhat in Libyan Arab Jamahiriya. Towards the interior areas a sharp drop in rainfall occurs due to the shadow barrier caused by the northern mountains. Table 1 illustrates average annual precipitation in selected sites in the NACs.

More than 80% of the total precipitation occurs in winter, affecting the rate of water flood of the main rivers in NAR. Apart from the Nile in Egypt, the rivers in the NAR are short and have a small annual discharge, e.g. Cheliff in Algeria and Tansift in Morocco. Drought years are common in the NAR. In the past few years recorded rainfall figures were below the average.

TABLE 1: AVERAGE ANNUAL PRECIPITATION IN SELECTED SITES

Station	Precipitation, mm	Station	Precipitation, mm
Algiers	762	Marsa Matrouh	125
Biskra	175	Oran	398
Cairo	33	Sallum	94
Constantine	564	Sebha	10
Dabaa	117	Shahhat	600
Dekheila	179	Tangier	825
Djerba	213	Tripoli	365
Essaouria	825	Tunis	454

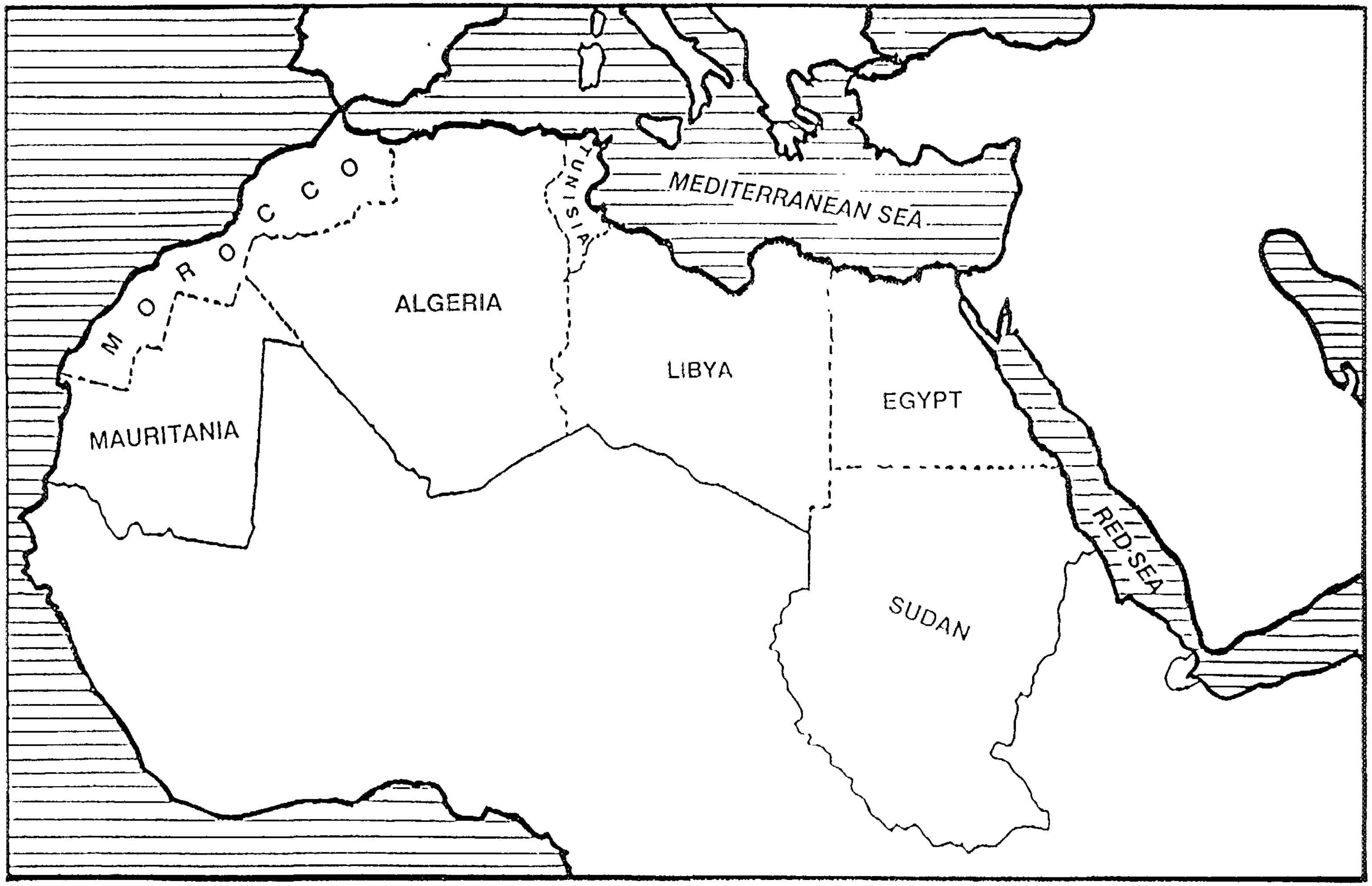


Fig. 1: Map of North African Countries

2.2 DEMOGRAPHY

In the past 40 years, the population of the NACs increased from 42.5 millions in 1950 to 117.8 millions in 1990 with an average annual growth rate of 2.58%. The development of the population from 1950 to 1990 is shown in Table 2. In 1988 the urban population of the NAR was 48% of the total population. It is expected that urbanization will continue at a fast pace and reach 70 - 80% of the population in 2025.

TABLE 2: DEVELOPMENT OF REGIONAL POPULATION 1950 - 1990

Year	Population, thousands					Total
	Algeria	Egypt	Libya	Morocco	Tunisia	
1950	8,675	20,395	1,025	8,934	3,469	42,498
1955	9,665	23,021	1,169	10,200	3,801	47,856
1960	10,769	25,984	1,333	11,645	4,163	53,894
1965	12,090	29,352	1,641	13,175	4,555	60,813
1970	13,661	32,566	1,948	15,359	5,055	68,589
1975	16,406	36,132	2,499	16,865	5,588	77,490
1980	18,244	40,089	3,085	19,082	6,343	86,893
1985	20,684	46,899	3,790	23,266	7,201	101,840
1990	25,068	53,804	4,656	26,246	8,063	117,837

It seems certain that the population of the NACs will continue to increase with fairly high growth rate. Population projections up to the year 2025, based on the World Bank growth rates [1], are presented in Table 3 and indicate an average annual growth rate of 1.8%.

TABLE 3: PROJECTIONS OF FUTURE REGIONAL POPULATION 1995 - 2025

Year	Population, thousands					Total
	Algeria	Egypt	Libya	Morocco	Tunisia	
1995	28,525	59,404	5,659	29,695	8,840	132,123
2000	31,426	65,587	6,813	33,597	9,630	147,053
2005	34,049	71,005	8,123	35,927	10,390	159,494
2010	37,982	76,868	9,593	38,418	11,083	173,944
2015	41,588	83,219	11,052	41,082	11,823	188,764
2020	44,106	90,093	12,550	43,931	12,611	203,291
2025	47,503	97,535	13,769	46,978	13,453	219,238

In the year 2000 the regional population is expected to be about 147 millions with an annual growth rate of 2.2%, in 2010 the population will be about 174 millions with an average growth rate of 1.7% during the period 2000-2010. In 2025 the population might be as high as 220 millions, i.e. about 100 millions more than the present population. This population increase will in turn increase the demand on the already strained potable water supply. Therefore, alternative sources of water supply, such as desalination, have to be utilized.

2.3 ECONOMY

In the 1950's the economies of the NACs were largely based on agriculture. Industry was limited to the processing of agricultural products. In the past years significant expansion has occurred in industry, mining, and tourism. The average per capita GDP in the NAR increased from 300 US$ in 1960 to 809 US$ in 1985, based on 1975 US$, corresponding to an average annual growth rate of about 4%. Table 4 summarizes the evolution of the GDP/capita in each of the NACs during this period. Analysis of GDP [2] in the five countries from 1981 to 1986 indicates that agriculture represented 12.5%, industry 48.2% and services 39.3%.

TABLE 4: EVOLUTION OF GROSS DOMESTIC PRODUCT PER CAPITA IN NORTH AFRICAN COUNTRIES. 1960 - 1985 (in 1975 US$)

Year	Country					Regional
	Algeria	Egypt	Libya	Morocco	Tunisia	
1960	617	227	513	297	345	300
1985	802	620	3917	671	869	809

* Source: UN Blue Plan [3]

During the three years 1987 - 1989, the annual increase in GNP was 2.0% in Algeria, 3.0% in Egypt, 11.5% in Morocco, and 3.5% in Tunisia. In Libya there was no increase in GNP due to the decrease in oil prices, contrary to the period 1976 - 1987, which witnessed an average increase in Libya's GNP of 3.6% per annum. Major sectors of the NACs economies are briefly described below.

2.3.1 Agriculture

Only a fraction of the Regional land area can be classified as agricultural land. These are estimated to be 3.4% in Egypt, 5.5% in Libya, and 20% in Morocco. Agricultural output of the NACs has achieved a growth rate of almost 3% in 1986 due to a remarkable output of cereals in Algeria and Morocco.

2.3.2 Industry

Manufacturing industries are well established in the Region, with differences in the level of industrialization from one country to another. In 1989 the manufacturing industries for the five countries showed significant improvement in industrial growth, with 5.4% the highest in Africa excluding OPEC members [4]. Table 5 shows the contribution of manufacturing in total value added within the NACs.

2.3.3 Natural Resources

The region is rich in mineral deposits. Non-hydrocarbon mineral resources include phosphates, iron ore and manganese. To a lesser extent there are also deposits of gold, nickel, cobalt and copper. Table 6 ranks these and other natural resources in terms of importance to the economy of each of the individual NAC.

TABLE 5: RANKING OF MANUFACTURING AS A PERCENTAGE OF TOTAL VALUE ADDED IN THE NORTH AFRICAN COUNTRIES

Year	Country				
	Algeria	Egypt	Libya	Morocco	Tunisia
1965	6.9	27.1	-	10.0	3.5
1985	9.7	14.7	3.5	13.0	4.8

TABLE 6: RANKING OF NATURAL RESOURCES IN THE NORTH AFRICAN COUNTRIES

Natural Resources	Country				
	Algeria	Egypt	Libya	Morocco	Tunisia
Crude Oil	1	1	1	-	1
Natural Gas	2	2	2	-	-
Iron Ore	3	3	-	2	3
Phosphates	4	4	-	1	2
Manganese	-	5	-	3	-
Limestone	-	6	-	-	-
Gypsum	-	7	3	-	-
Talc	-	8	-	-	-
Asbestos	-	9	-	-	-
Lead	6	10	-	4	4
Zinc	7	11	-	7	5
Copper	-	-	-	-	-
Uranium	5	-	-	-	-
Mercury	8	-	-	-	-
Salt	-	-	-	9	7
Fish	-	-	-	8	6
Silver	-	-	-	6	-
Cobalt	-	-	-	5	-

3. REGIONAL WATER SUPPLY AND DEMAND ANALYSIS

3.1 GENERAL

Despite recent advances in desalination technologies, desalination as a source of potable water cannot compete with available natural resources. Therefore, water resource analysis is a vital component in any desalination feasibility study. Another vital component is the projected future water demand, supply and deficit.

In this chapter, the NACs' fresh water resources, supply and demand are presented. The information presented is based on the NACs' input to the feasibility study, complemented by data from other sources [5, 6]. Fresh water resources are classified into natural and processed resources.

3.2 ANALYSIS OF WATER RESOURCES

3.2.1 Natural Fresh Water Resources

Natural resources of fresh water are classified into surface and ground water resources. Surface water resources include rivers, lakes, springs, as well as rainwater run off intercepted by dams or collected in cisterns. Groundwater resources include rechargeable and non-rechargeable (fossil) aquifers.

These natural resources, as well as the national programmes to develop them, varies from one country to another. Therefore, in the following sub-sections the natural water resources will be discussed on a country by country basis. Tables 7 and 8 summarize the regional surface and ground water resources. The main obstacles to developing conventional water resources in the NACs are shown in Table 9.

TABLE 7: SUMMARY OF SURFACE WATER RESOURCES IN NORTH AFRICA

Country	Resources, Mm^3/y		
	Potential	Utilized	%
Algeria	5,700	2,000	35.1
Egypt	65,500	55,500	84.7
Libya	350	60	17.1
Morocco	16,000	7,500	46.9
Tunisia	2,700	1,396	53.7
Total	90,250	66,456	73.6

TABLE 8: SUMMARY OF GROUND WATER RESOURCES IN NORTH AFRICA

Country	Resources, Mm^3/y		
	Potential [(a)]	Utilized	%
Algeria	6,800	2,800	41.2
Egypt	7,400	3,100	41.9
Libya	3,195	4,655	133.2
Morocco	5,000	3,000	60.0
Tunisia	1,840	1,536	83.5
Total	24,235	15,091	62.3

(a) Estimated on the basis of long-term extraction capability of fossil aquifers, and the recharge rate of non-fossil aquifers. For more details refer to Table 11.

TABLE 9: CONSTRAINTS ON IMPLEMENTATION OF WATER PLANS IN NORTH AFRICA

Problem	Algeria	Egypt	Libya	Morocco	Tunisia
a) Surface Water					
- Common Basin Agreements		X			
- Low Precipitation		X	X		
- Irregular Precipitation	X		X	X	X
- Pollution		X			
- Sedimentation	X	X			
b) Groundwater					
- Scarce			X		
- Fossil		X	X		
- Seawater Intrusion		X	X		X
- Depleted			X		X
- Polluted		X			X
c) Economic	X	X		X	X

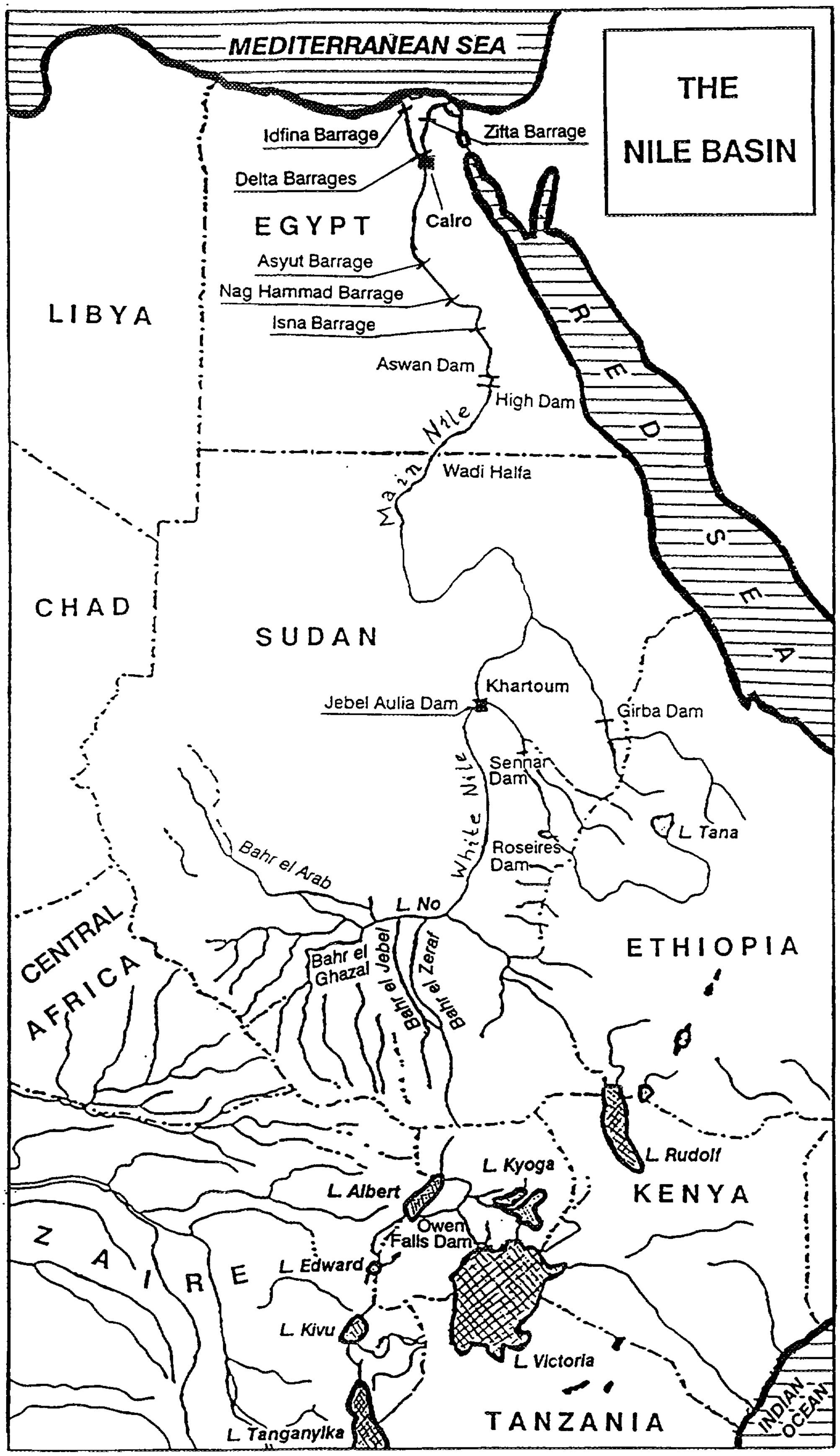


Fig. 2: The Nile basin

3.2.1.1 Natural Fresh Water Resources in Algeria

Rain is the main source of natural fresh water resources (surface and ground) in Algeria. The average precipitation varies from 1500 mm/y in the North East to less than 100 mm/y in the Southern desert. The corresponding rates of evaporation are 1200 mm/y and 2500 mm/y respectively. Surface water resources consist of rain water runoffs in valleys, the estimated total theoretical potential of which is estimated to be about 12.4 Bm^3/y distributed among the following basins:

- The Mediterranean Basin (11.0 Bm^3/y).
- The high Atlas ranges (0.70 Bm^3/y).
- The Desert basin (0.70 Bm^3/y).

Of the above mentioned potential, only 5.7 Bm^3/y can be utilized, even if 100 regulation and compensation dams are built. However due to the small number of dams that already exist, a large amount of rainwater is lost into the sea. There are three major problems facing the Algerian plans to develop surface water resources through construction of dams to intercept rain water. These are:

- High rate of sedimentation of silt carried out by water run off, which is estimated to be between 200,000 and 600,000 ppm.
- Irregularity of rainfalls with respect to time of the year and/or place.
- Uneven distribution of natural water resources with respect to population demand.

At the moment, 2.0 Bm^3/y are utilized through 100 dams. Another 27 dams are under construction to add 1.1 Bm^3/y to the existing resources.

Rechargeable aquifers are concentrated in the north of the country. The average recharge rate is estimated to be 1.7 Bm^3/y. There is also a large amount of fossil water stored in the southern aquifers which can be exploited at a rate of 5.0 Bm^3/y. However, only 20% of that potential is currently utilized. The cost of water utilization in the South is relatively high, which makes it uneconomic for agriculture.

3.2.1.2 Natural Fresh Water Resources in Egypt

The River Nile is the only significant source of surface water in Egypt, as well as the largest source of surface water in the Region. Figure 2 shows a map of the Nile Basin including all tributaries. The 1959 treaty with Sudan fixes Egypt's share from the Nile at 55.5 Bm^3/y. This share can be increased by about 10 Bm^3/y through implementing conservation projects in the Upper Nile Basin. However, the implementation of these projects has been delayed because of the civil war in Sudan. Due to uncontrolled urban growth, rapid industrialization and environmental impact of the High Dam, water quality of the Nile has deteriorated because of pollution and algae growth. Although the Egyptian bioclimate varies from arid to extremely arid, rainwater contributes to the irrigation of a narrow strip of cultivated land in the North Coast and Sinai. It is also collected in cisterns to be used for drinking in remote western coastal areas such as Sidi Barrani and Sallum, where it is considered the principal water supply source.

Groundwater utilization in Egypt dates back to ancient times. The Nile Valley and Delta aquifer is continuously recharged by irrigation water. The total storage capacity of the aquifer amounts to 500 Bm^3. The present extraction of 2.6 Bm^3/y can be increased to 4.9 Bm^3/y without causing salt intrusion in the Nile Delta. Groundwater in the inland desert areas is characterized by the absence of direct recharge. The huge amount of water stored in the Nubian Sandstone Basin (200,000 Bm^3), is mainly fossil and mostly available at great depth. Potential exploitation is estimated to be 2.5 Bm^3/y. However, the present extraction rate from these aquifers is estimated to be only 0.5 Bm^3/y.

Egyptian plans to develop water resources include: increasing agricultural drainage reuse from the present 4.7 Bm^3/y to 7 Bm^3/y, the reduction of navigation water during winter shut down of water works from the present 1.8 Bm^3/y to 0.3 Bm^3/y, and improving the efficiency of irrigation and water management. This will require a change of habits and social behavior which is usually difficult to achieve.

3.2.1.3 Natural Fresh Water Resources in Libya

Libya is a very arid country. The average precipitation ranges between 10 to 500 mm/y. The area above the 100 mm/y precipitation line is less than 5% of the country's total area. The evaporation rates are high, ranging from 1700 mm/y in the north to 6000 mm/y in the middle and southern regions. Therefore, groundwater is the main source of fresh water in Libya, and provides more than 98% of the water supply. It occurs in aquifers of varying thickness, ages, and lithological composition.

Groundwater recharge is estimated to be 500 Bm^3/y which is extremely small in comparison with present groundwater extraction. Currently, groundwater extraction potential is estimated to be 4.655 Bm^3/y. At the moment, most of groundwater supply is obtained from coastal aquifers. Large extraction led to a sharp decline in water levels followed by sea water intrusion.

To overcome this situation, the Great Manmade River Project (GMRP) was launched in 1983 aiming at conveying 6.1 Mm^3/d from Sarir, Kufra and Murzuk basin in the south to the coastal plains. The GMRP is planned to be completed by the turn of the century and consists of the following five phases [7]:

- Phase I: In this phase a total of 2 Mm^3/d will be conveyed from Saris and Tazirbu basins to coastal areas extending from Benghazi to Sirt. This phase was completed in 1993.
- Phase II: In this phase, 2.5 Mm^3/d will be conveyed to the Gefara Plain in the north-west of Libya, from the Urzuk basin. This phase is expected to be completed by the year 2000.
- Phase III: In this phase, 1.6 Mm^3/d will be added to phase I from an additional well-field south of Kufra. This phase is expected to be completed by the year 2010.
- Phases IV & V: These two phases are oriented towards further extensions of the conveyance line of Phase I eastward to reach Tobruk and westward to link with Phase II along the western coast.

The purpose of GMRP fresh water supply is mainly for agriculture, with some industrial use and potable supply. However, according to the Libyan officials, the quality and quantity of drinking water is not sufficient to satisfy demand in these areas.

Surface water resources in Libya are limited and contribute only a small amount to the total water consumption. The total runoff volume is estimated to be about 257 Mm^3/y. Few springs of small to medium discharge are located in different parts of the country providing an annual discharge of 150 Mm^3/y. To intercept the maximum possible run off water, sixteen dams with a total storage capacity of 387 Mm^3 and an average capacity of 60 Mm^3/y, were constructed.

The main obstacle to developing water resources in Libya is the extremely low and irregular precipitation in most of the country. This could render dams, built to intercept rainwater, useless. Therefore, national water plans are based on exploiting fossil aquifers, and utilization of unconventional resources such as seawater desalination.

3.2.1.4 Natural Fresh Water Resources in Morocco

Most of Moroccan rivers depend on rainwater, which is estimated to be 125 Bm^3/y. These are concentrated in a few months or even a few days of the year, as in the case of the Southern Atlantic Basins, which result in short and strong floods. Seventy large dams, with total storage capacity of 11 Bm^3, were constructed allowing the utilization of 7.5 Bm^3/y out of the surface water potential of 16 Bm^3/y.

The potential rechargeable groundwater resources are estimated to be 5 Bm^3/y, 60% of which are actually utilized. These are extracted from about 40 shallow aquifers and another 40 medium and deep aquifers.

The total utilized water resources in 1990 is estimated to be 5.7 Bm^3/y. Future projections also indicate that the available resources will exceed the overall demand. Therefore, unconventional water projects do not seem to be high on the agenda at present.

The main problem facing the implementation of water plans in Morocco is the irregularity of rainfalls, which results in discontinuous runoffs and irregular recharge of aquifers. Another important problem is the uneven distribution of water resources between the different regions in the country.

3.2.1.5 Natural Fresh Water Resources in Tunisia

Water resources in Tunisia depend on rainfall, which varies between 100 mm/y in the far south to 1500 mm/y in the far north of the country. The corresponding evaporation rates are 2000 and 1250 mm/y respectively.

Surface water resources amount to 60% of the total water resources. These are estimated to be 2700 Mm^3/y. The Northern Region provides 2176 Mm^3/y i.e. 81% of the total. The Central Region provides 380 Mm^3/y (14% of total) while the Southern Region provides 144 Mm^3/y (5% of the total). However, these are irregular resources due to irregular raining. For example, in 1991 surface water resources were only 1335 Mm^3/y of which 400 Mm^3/y was actually utilized, compared to 1396 Mm^3/y or 53.7% of the surface water resources utilized in 1990. Therefore, it is considered secondary in importance when compared with groundwater, which is considered the main source of fresh water in Tunisia because it is more regular in quantity and quality.

In Tunisia, groundwater resources are estimated to be 1840 Mm^3/y, of which 625 Mm^3/y is in shallow aquifers and 1215 Mm^3/y in deep aquifers. The Northern Region provides 505 Mm^3/y, the Central Region provides 492 Mm^3/y and the Southern Region provides 843 Mm^3/y. These represent 27%, and 46% respectively of the total groundwater resources. The utilized resources are estimated to be 1536 Mm^3/year or 83.5% of the available resources.

3.2.2 Processed Fresh Water Resources

Processed water resources include desalination plants and sewage treatment plants. These are discussed below.

3.2.2.1 Desalination Plants

Seawater is the largest water source available in the region and indeed in the world. Compared with existing fresh natural resources, its availability is essentially unlimited. Desalination plants of various sizes and technologies have been introduced into the region in the past 20 years as a solution to the problem of limited natural fresh water resources. IDA [6] indicated that the total installed desalting capacity in the region was about 900,000 Mm^3/d (327 Mm^3 /year) at the end of 1989.

Table 10 shows the desalination inventory of the NACs. The largest desalting capacity exists in Libya with 69.1% of the total regional installed capacity, followed by Algeria with 19.7%. For more details refer to Chapter 9. The inventory is shared between industry in the region as a whole with 44.4% of the total installed capacity and municipal use which is about 47%. Most of the desalting capacity for municipal, touristic, and military uses, as well as those used by petroleum exploration companies (classified as industrial), are directed towards the production of drinking water.

TABLE 10: DESALINATION INSTALLED CAPACITIES IN THE NORTH AFRICAN REGION AT THE END OF 1989

Country	Algeria	Egypt	Libya	Morocco	Tunisia	Total
Inventory (m^3/d)	176,087	67,728	619,354	9,581	22,870	895,620
%	19.7	7.6	69.1	1 1	2.5	100.0

3.2.2.2 Sewage Treatment Plants

A potential water resource to be considered is treated sewage water. Re-use of sewage water after primary treatment in agriculture has been practiced since 1925 in Egypt at Al-Gabal Al-Asfar, North East of Cairo in an area of 1,650 hectares. The completion of the new Greater Cairo Sewers will permit the treatment of up to 1.5 Bm^3/y which can be used in irrigating a further 168,000 hectares of the desert land. Additional sewage water effluent from other major cities in Egypt may bring the total treated sewage water up to 2.5 Bm^3/y.

In Libya, special attention is also given to sewage treatment. Treated water is used for irrigating orchards, fodder and other indirectly consumed crops. There are already 13 treatment plants operating in Libya with a total capacity of 86,000 m^3/d, the largest of which is in Tripoli having a capacity of 40,000 m^3/d. There are also six plants under construction adding a further 38,000 m^3/day to the existing capacity. The additional 17 plants with total capacity of 162,000 m^3/d are currently in the design phase.

In Tunisia, there are 10 treatment plants, the largest of which is in Tunis (10,000 m^3/d).

3.2.3 Analysis of Regional Fresh Water Supply

The successful implementation of a water plan requires: i) the identification of potential water resources that can be utilized economically, ii) the identification of water needs for various activities. The NACs' water plans to develop water supply and the corresponding balance between supply and demand up to 2025 are not available. However, the future projections up to the year 2000 are available [5] and are summarized in Table 11. It is obvious from the Table that Libya suffers already from an overall deficit in available water supply. This is compensated by the over-exploitation of rechargeable groundwater resources, or by reduction of water supplied to different sectors by the ratio of supply to demand.

In Algeria, the percentage of fresh water allocated to drinking is much higher than that for industrial use. The overall balance of supply and demand indicates a surplus of 0.834 Bm^3/y in 2000. This will depend on the successful implementation of plans to increase the utilization of surface and fossil ground water resources.

In Egypt, there was a surplus of 3.37 Bm^3/y in 1990. This is expected to be reduced to 0.26 Bm^3/y in the year 2000. The Egyptian plans to carry out conservation projects in the upper Nile came to a halt as a result of political unrest in Sudan and other source countries on the Nile basin. Therefore, increasing the supply sources depends primarily on drainage water-reuse and conservation projects. If either of these is not implemented successfully, the narrow margin of surplus could be endangered. Hence, an overall deficit could exist in the year 2000.

The situation in Libya is similar to that of Algeria with respect to the mismatch between water allocated for drinking and for industrial uses, as indicated in Table 11. However, the overall deficit in fresh water will persist. The successful implementation of water plans will only reduce the deficit from 4.093 Bm^3/y in 1990 to 3.190 Bm^3/y in the year 2000. Therefore, the high extraction rates of northern aquifers will continue, leading to further deterioration of their quality due to salt intrusion.

In Morocco, drinking water represented 15.7% of the total demand in 1990, and is expected to increase to 25.8% of the total demand in 2000. The corresponding industrial water requirements are 3.6% and 5.6% respectively. Due to huge fresh water resources in Morocco, as was shown in the previous Sections (also in Table 11), projects to tap unconventional water resources are not considered in the Moroccan water plans, except in Laayoune.

The Tunisian projections, as shown in Table 11, indicate that there is a trend to increase water allocations for industrial uses from 3.2% of the total demand in 1990 to 3.8% in 2000, as well as decreasing irrigation requirements from 84.6% to 82.1% in the same period.

The severe water shortage in Libya combined with the limited and declining water resources necessitates the utilization of desalination technology to meet the growing water needs. At the same time, the projected limited fresh water shortage in the other NACs strengthens the possibility of seawater desalination in these countries, particularly in locations where the indigenous fresh water resources are limited.

3.2.4 Concluding Remarks on the Regional Water Situation

The Region of North Africa lies, for the most part, within the temperate zone and the bioclimate varies from arid to extremely arid. Surface water in the region includes rivers and rain water intercepted by dams or collected in cisterns. These, however, are limited and/or suffer from low and irregular precipitation, as well as pollution due to uncontrolled urban growth.

Groundwater resources play an important role in providing fresh water in the NAR, particularly in places where surface water resources are limited such as Libya. Most of these resources are fossil and available at great depth. In the northern areas, large extraction led to a sharp decline in water levels followed by seawater intrusion. Therefore, groundwater resources are, generally, in limited supply and declining.

Due to uneven distribution of water resources in the NACs, the water resources in several locations are either inadequate in quality (e.g. Southern Tunisia) or quantity. Therefore, the development plans in these locations will require fresh water that can only be provided through costly investments such as water transport from surplus to shortage areas, brackish water desalination, new dams, or seawater desalination.

Under some circumstances, seawater desalination can compete with the other alternatives, particularly for remote sites within reasonable transport distance from the sea. Indeed, eleven such sites have been identified by the NACs as sites requiring desalination plants of various capacities to satisfy the development water requirements (refer to Chapter 5).

TABLE 11 : SUMMARY OF NORTH AFRICAN WATER SUPPLY AND DEMAND PROJECTIONS

Country	Algeria		Egypt		Libya		Morocco		Tunisia		Total	
Year	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000
Population, Millions	25 0	31 4	53 8	65 6	4 7	6 8	26 2	33 6	8 1	9 6	117 8	147 1
Available water resources, BM^3/Y												
Surface water	2 0	2 9	55 5	55 5	0 06	0 12	8 5	11 0	1 4	2 7	68 56	73 82
Groundwater												
* rechargeable	1 7	1 8	2 6	4 9	0 5	0 5	3 0	5 0	0 70	0 84	9 00	11 54
* fossil	1 1	2 5	0 5	2 5	0 0	1 64	-	-	0 84	1 00	2 44	7 64
Total Groundwater	2 8	4 3	3 1	7 4	0 5	2 16	3 0	5 0	1 54	1 84	11 44	19 20
Other water resources												
* drainage reuse	-	-	4 7	7 0	-	-	-	-	-	-	4 7	7 0
* Sewage treatment	-	-	0 2	1 1	0 034	0 054	-	-	-	-	0 234	1 154
* desalination	0 064	0 084	0 033	0 065	0 070	0 073	0 003	0 004	0 008	0 011	0 171	0 205
* conservation	-	-	-	1 0	-	-	-	-	-	-	0 0	1 0
Total other	0 064	0 084	4 933	9 165	0 104	0 127	0 003	0 004	0 008	0 011	5 105	9 359
Total available resources	4 864	7 284	63 52	72 03	0 664	2 389	11 5	16 0	2 948	4 551	85 105	102 38
Fresh water demand BM^3/Y												
* drinking	1 3	1 95	3 691	5 112	0 408	0 647	0 832	1 849	0 309	0 407	6 540	9 965
* %	30 7	30 2	6 2	7 2	8 6	11 6	9 1	15 6	12 2	15 0	8 5	10 8
* Industrial	0 214	0 5	4 6	6 1	0 074	0 132	0 19	0 404	0 08	0 103	5 158	7 239
* %	5 0	7 8	7 7	7 7	1 6	2 4	3 6	5 6	3 2	3 8	6 7	7 8
* irrigation	2 727	4 0	49 7	59 9	4 275	4 80	8 35	10 0	2 067	2 2	63 05	75 89
* %	64 3	62 0	83 1	83 9	89 8	86 0	90 9	84 4	84 6	81 2	82 4	81 3
* other	-	-	1 80	0 30	-	-	-	-	-	-	1 80	0 30
* %	-	-	3 0	0 4	-	-	-	-	-	-	2 4	0 1
Total demand BM^3/Y	4 241	6 450	59 79	71 41	4 757	5 579	9 182	11 849	2 536	2 710	76 55	93 36

Generally, in view of the limited renewable fresh water resources in most of the NACs and the unavoidable decline of fossil water resources, seawater desalination will play an increasing role in mitigating future deficit. Desalination plants of various sizes and technologies have already been introduced into the region during the last 20 years as a solution to the problem of limited natural fresh water resources.

3.3 POTABLE WATER SUPPLY AND DEMAND

3.3.1 Historical Development

Following the independence of Algeria in 1962, the production of potable and industrial water was about 250 Mm^3/y for a total population of 9 million. In 1990, the water supply was 1300 Mm^3/y for a total population of 25 million inhabitants. This supply was obtained from dams (21.4%), drill holes (72.6%) and springs (6%). Industrial water supply represented 12% of the total supply. Accurate records for potable water consumption exist in Egypt from 1963. The urban water consumption increased from 660 Mm^3/y in 1965 to more than 2500 Mm^3/y in 1990. The urban population increased from 11.64 to 23.66 million in the same period. Rural consumption was estimated to be 320 Mm^3/y in 1965 and 1100 Mm^3/y in 1990, with corresponding population of 17.71 and 30.14 million respectively. During the same period the total per capita consumption increased from 91 to 188 liter per capita per day (LCD).

In Libya, demand for drinking water is growing rapidly in conjunction with population growth, improvement in the standard of living, and urbanization (in 1980 urban population was 60.7% of the total). In 1978, a survey to determine water consumption in Tripoli indicated a specific consumption of 270 LCD. Average specific consumption of 230 and of 240 LCD were estimated for the country as a whole in 1984 and 1990, respectively. The population increased from 3.64 to 4.66 million in the same period. Thus the total consumption increased from 305 Mm^3/y in 1984 to 408 Mm^3/y in 1990.

In Morocco, the overall demand for drinking water increased from about 175 Mm^3/y in 1965 to 832 Mm^3/y in 1990. The annual rate of increase in water consumption decreased from 8% in the period 1965-1975 to 6.2% in the period 1975-1985. In the decade 1985-1995 it is expected to drop further to 4.1%. This trend was attributed to a decrease in population growth rate, coupled with effective implementation of plans to reduce losses in the water distribution system and construction of water treatment plants.

In 1989 potable water consumption in Tunisia was 192.4 Mm^3/y, 63% of which was for domestic uses, 12% for industrial uses and 25% for public, touristic and other uses. The consumption is expected to increase at an annual rate of 1.5% till 2025.

3.3.2 Forecast of Regional Potable Water Demand

Different methodologies were used by each country to project the future demand of potable water. These methodologies varied in their complexity and their efforts to determine the factors influencing the future water consumption. In the review presented below, potable water consumption is measured at the outlet of the water source, i.e. transmission and distribution losses are included.

The Algerian forecast [8] was based on the assumption that the 1987 needs correspond to those specified by the WHO as follows:

Community Population (thousands), P	Specific Consumption, C
P < 50	C = 150 LCD
50 < P < 500	C = (2P + 1250)/9 LCD
P > 500	C = 250 LCD

For the future demand projections, an annual increase of 1% in the above specific consumption was assumed. Total consumption was obtained through combining the projected specific consumption and population forecasts. The losses were assumed to be 20% (presently they are between 40% and 50%). Detailed projections were given for urban demand in the period 1990-2010. Total demand projections were given for the years 2010 and 2025. These data were manipulated to yield the projections listed in Table 12.

TABLE 12: PROJECTIONS OF POTABLE WATER DEMAND IN THE NORTH AFRICAN COUNTRIES

	Water Demand, million Mm^3/y					Total	
Year	Algeria	Egypt	Libya	Morocco	Tunisia	Mm^3/y	Mm^3/d
1995	1770	4354	516	1376	446	8462	23 2
2000	1950	5112	647	1849	510	10064	27.6
2005	2150	5701	815	2173	570	11400	31.3
2010	2440	6777	1015	2560	632	13426	36.8
2015	2960	7751	1251	3002	705	15669	42.9
2020	3590	8829	1512	3527	786	18244	50.0
2025	4300	10019	1759	4000	877	20955	57.4

To project the future demand of potable water in Egypt, the history of past consumption was studied [9] and correlation were obtained between consumption and other variables such as population growth or electricity consumption. For the urban demand forecast, three approaches were used. These were:

i) Population vs. potable water consumption.
ii) Electricity generation vs. potable water consumption.
iii) Constant per capita consumption of 274 LCD corresponding to that obtained during the 1980's.

The average of the three forecasts yielded an average increase in specific consumption of about 1 LCD annually which was taken to represent the base case. For the rural demand forecast, it was assumed that the specific consumption will increase by 3 LCD annually [10].

In order to estimate the future potable water demand in Libya [11], the average specific consumption of 230 LCD in 1984 was considered to be representative for the whole population. An annual rate of increase in specific consumption of only 1% was assumed for future projections. No distinctions were made between urban and rural areas with respect to specific consumption.

In Morocco, the forecast for water demand [12] was based on analysis of the demands of the water consuming sectors, namely: domestic, industrial, and public users. The analysis indicated that the potable water demand will increase annually by 10.6%, 6.1%, and 3.3% and 2.5% in the periods 1990-1995, 1995-2000, 2000-2020, and 2020-2025, respectively.

The Tunisian forecast [13] was based on the assumption of an average annual growth rate in potable water consumption of 2.3% and a growth rate of total population decreasing from 1.9% in 1990 to 1.3% in 2005, and remaining constant thereafter. The corresponding specific water consumption increases from 132 LCD in 1990 to 262 LCD in 2025.

Table 12 summarizes the expected future demand of potable water in the five North African Countries. The corresponding specific consumption are listed in Table 13. These were calculated using population forecasts given in Table 13.

TABLE 13: PROJECTIONS OF SPECIFIC WATER DEMAND IN THE NORTH AFRICAN COUNTRIES

	Specific Water demand, LCD					
Year	Algeria	Egypt	Libya	Morocco	Tunisia	Regional
1995	170	201	255	127	176	176
2000	170	214	270	150	145	190
2005	173	220	285	166	150	190
2010	176	242	300	183	156	213
2015	195	255	315	200	161	228
2020	223	268	330	220	171	246
2025	248	281	345	233	178	261

Table 12 shows that about half of the Regional demand for potable water is required by Egypt. The Table also shows that the Regional demand for potable water in the year 2025 could be as high as 57 Mm^3/d, i.e. about 3 times the present consumption of 18.1 Mm^3/d.

Accurate estimation of the future deficit in potable water supply requires information on the economic life of the present potable water sources, as well as committed future plans to develop new supply sources (e.g. purification stations, desalination plants etc.). Unfortunately, such information is not available at the present moment. Therefore, in order to estimate the future deficit up to the year 2025, the 1990 capacity shown in Table 14 was assumed to be available till 2025.

TABLE 14: POTABLE WATER SUPPLY IN 1990

Country	Supply, Mm^3/y	Specific Consumption, LCD
Algeria	1300	142
Egypt	3691	188
Libya	408	245
Morocco	832	87
Tunisia	389	132
Total	6620	155

The deficit was calculated through subtracting the 1990 supply from the projected future demand. The results are depicted in Table 15. It is worth mentioning that the development of potential water resources within each NAC, with the exception of Libya, could cover this deficit through:

i) drilling of wells and construction of dams (Algeria, Morocco, Tunisia);
ii) water transfer (Algeria, Egypt, Morocco, Tunisia);
iii) water projects outside the country (Egypt);
iv) conservation projects (Egypt).

Desalination of brackish and seawater represent the most economic solution in remote locations or in particular areas within the NACs where the available and potential resources cannot satisfy the demand. Examples are: Oran region in Algeria, North west coast in Egypt, Laayoune in Morocco, and South Tunisia.

The amount of brackish and/or polluted water currently consumed as drinking water within the Region is estimated to be about 3 Mm^3/d. This amount represents a deficit that must be added to those depicted in Table 15 because it has to be substituted by clean potable water from other sources. Thus, by the year 2025 the deficit might be as high as 42 Mm^3/d.

TABLE 15: PROJECTIONS OF POTABLE WATER DEFICIT IN THE NORTH AFRICAN COUNTRIES

	Water Deficit, Mm^3/y					Total	
Year	Algeria	Egypt	Libya	Morocco	Tunisia	Mm^3/y	Mm^3/d
1995	470	663	108	544	57	1842	5 0
2000	650	1421	239	1017	121	3445	9.4
2005	850	2010	407	1341	181	4789	13.1
2010	1140	3086	607	1728	243	6804	18 6
2015	1660	4060	843	2170	316	9049	24.8
2020	2290	5138	1104	2695	397	11624	31.8
2025	3000	6328	1351	3168	488	14335	39 3

4. REGIONAL ENERGY SUPPLY AND DEMAND ANALYSIS

4.1 GENERAL

Any desalination process will require energy in one form or another. The distillation processes, MED or MSF, require steam heating to produce vapor from seawater that would be condensed to yield fresh water. On the other hand, for membrane desalination methods, RO and the vapor compression process, VC, pumping power is required and is usually supplied through electric motor driven pumps. Thus, a survey of the available energy resources for providing heat and electricity is also necessary.

In this section an analysis of both energy resources and electricity supply and demand in the North African Countries is presented, based on data presented by participating countries and supplemented by data from other sources [14, 15].

4.2 ANALYSIS OF ENERGY RESOURCES

The analysis of the structure of the prevailing energy market includes:

- Final energy consumption by energy forms and sectors.
- Energy production by energy sources and forms.

In the present analysis, the structure and definitions adopted by the World Energy Conference (WEC) [14], will be used. The energy resources considered are:

1. Coal (including lignite)
2. Crude oil and Natural Gas Liquids
3. Oil shale and Natural Bitumen
4. Natural Gas
5. Uranium
6. Hydraulic Energy
7. Peat
8. Wood (including charcoal)
9. Biomass (other than wood)
10. Solar Energy
11. Geothermal Energy
12. Wind Energy
13. Oceanic and Tidal Energy.

The history of direct energy consumption of the NAR by energy forms is presented in Table 16. It shows that electricity represented about 10% of the energy market over the past 20 years. In 1987, total energy consumption in the Region amounted to approximately 44 Million Tons of Oil Equivalent (MTOE). Oil accounted for 72%, coal for about 3%, gas for 12%, and electricity for 13%. Table 16 also indicates that energy consumption increased from about 12 MTOE in 1971 to about 44 MTOE in 1987, i.e. an average annual increase of total consumption of about 8.5%. The available and potential energy resources of the individual NACs, as well as the Region as a whole, are presented in the following sections.

4.2.1 Coal

The first effort to discover coal in the NAR was made in Egypt in 1844, where carbonic substances were found in Ein Yassin. Few coal deposits have since been discovered in Algeria, Egypt and Morocco. The only coal producing country in the NAR is Morocco where the average annual production of coal is about 0.5 million tons. Coal deposits in Algeria and Egypt either have not been sufficiently characterized, have poor geological characteristics, or are uneconomical to exploit at the present time. Table 17 shows the regional coal resources and reserves at the end of 1990 which represents 0.23% of the proved recoverable reserves in Africa.

TABLE 16: DEVELOPMENT OF DIRECT ENERGY CONSUMPTION BY ENERGY FORMS FOR THE NORTH AFRICAN REGION (MTOE)

	Energy Form				
Year	Coal	Oil	Gas	Electricity	Total
1971	0.8	9.8	0.3	1.0	11.9
1973	0.6	11.7	0.4	1.2	13.9
1975	0.8	14.3	0.5	1.5	17.1
1977	0.8	17 1	1.1	2.0	21.0
1979	1.0	20.2	2.8	2.3	26.3
1981	1 2	23.8	4.1	3.1	32.2
1983	1.2	27.2	4.6	3.8	36.8
1985	1.3	31.2	5.0	4.9	42.4
1987	1.4	31.9	5.3	5.4	44.1

Source Reference [15].

TABLE 17: REGIONAL COAL RESOURCES AND RESERVES AT END OF 1990[1] (Million Tons)

Country	Rank of Fuel [2]	Proved Amount in Place	Proved Recoverable Reserves
Algeria	BT	-	43
Egypt	BT	25	13
	SB	-	40
Libya	-	-	-
Morocco	BT	134	45
	LN	44	-
Tunisia	-	-	-
Total		203	141

(1) Source Reference [14]

(2) BT = Bituminous including anthracite, SB = Sub-bituminous, LN = Lignite.

At present, most of the coal used in the region is imported. Table 18 shows the development of coal consumption in the NAC's. In Algeria, Egypt, and Tunisia most of the coal has been consumed by industry, particularly the iron and steel industry. The major coal consumer in Morocco is the electricity generating sector. In oil rich Libyan Arab Jamahiriya, coal is not part of the national energy mix.

TABLE 18: DEVELOPMENT OF REGIONAL DEMAND FOR COAL (1000 Tons)

Year	Country					Total
	Algeria	Egypt	Libya	Morocco	Tunisia	
1971	47	570	-	472	31	1120
1973	73	477	-	582	33	1165
1975	49	895	-	679	40	1663
1977	47	968	-	731	20	1766
1979	91	1110	-	558	33	1792
1981	666	1154	-	753	26	2599
1983	731	1113	-	767	28	2639
1985	848	1192	-	650	21	2711
1987	1049	1250	-	1317	16	3632

* Source reference [15]

4.2.2 Crude Oil and Natural Gas Liquid

In 1990, the NAR contained 67% of the proved recoverable oil reserves in Africa and 4.5% of the world oil reserves. Table 19 shows the Regional crude oil resources and reserves at the end of 1990. With the exception of Algeria, Natural Gas Liquid (NGL) reserves are insignificant. NGL proved recoverable reserves in Algeria are estimated to be 600 million tons.

TABLE 19: REGIONAL CRUDE OIL RESOURCES AND RESERVES AT END OF 1990. (Million Tons)

Country	Proved Amount in Place	Proved Recoverable Reserves	Estimated Additional Amount in Place	Estimated Additional Reserves Recoverable
Algeria	7600	1800	-	360
Egypt	-	840	220	-
Libya	-	3150	-	-
Morocco	-	0.3	-	-
Tunisia	-	230	62	-
Total	7600	6020	282	360

* Source Reference [14]

Table 20 shows the development of crude oil and NGL production, consumption, and exports. Comparison between Tables 19 and 20 reveals that with the present production rate and the available reserves, oil will be depleted completely in about 30 years unless new discoveries are made.

TABLE 20: DEVELOPMENT OF CRUDE OIL AND NGL PRODUCTION, CONSUMPTION, AND EXPORTS IN THE NORTH AFRICAN REGION (Million Tons)

Year	Prod.	Cons.	Export	Year	Prod.	Cons.	Export
1970	-	-	-	1980	176.4	29.7	145.7
1971	188.0	12.4	179.3	1981	143.3	33.0	110.8
1972	176.6	14.2	166.3	1982	139.7	36.1	98.3
1973	171.7	14.7	162.4	1983	140.5	39.3	96.7
1974	135.4	16.2	123.0	1984	149.6	41.1	101.0
1975	138.7	18.2	124.9	1985	151.8	42.5	102.5
1976	167.9	20.8	149.3	1986	149.1	42.6	95.6
1977	182.0	23.1	159.0	1987	153.3	43.5	97.7
1978	187.2	24.5	163.4	1988	-	-	-
1979	189.2	27.5	168.4	1989	-	-	-

* Source Reference [15]

4.2.3 Oil Shale and Natural Bitumen

Sedimentary rocks which have a high proportion of organic matter (kerogen) are categorized as oil shale. Bitumen is defined as oil with viscosity greater that 10,000 centipoise at reservoir temperature and atmospheric pressure. The significant decline in oil prices which started in 1986 has impaired large scale commercial development of oil shale and natural bitumen world wide. Many development projects which were in the planning stage prior to 1986 have been delayed or put on hold.

The only country in the region with significant oil shale reserves is Morocco. Proved recoverable reserves are estimated to be 100 billion tons. The average yield of oil is 70 kg/ton, i.e. about 6 billion tones of oil can be produced from oil shale in Morocco. Oil shale deposits have been located also in several places in Egypt. However, studies indicated that the shale is of low quality and could be exploited only in response to a severe shortage of fuels.

4.2.4 Natural Gas

The past two decades have seen a tremendous increase in production and consumption of natural gas in the region. Marketed production of natural gas increased from about 4 MTOE in 1971 to almost 46 MTOE in 1987, as can be seen in Table 21. Table 22 shows the regional natural gas resources and reserves at the end of 1990. The prospects for the gas industry in the region for the coming years are favorable. Proved reserves represent 68 years of production at the current rate.

In both Egypt and Morocco the demand for gas is just met by production. In Tunisia, as of 1984 indigenous production is not enough to meet the demand. Currently about 60% of the Tunisian requirements of gas are imported. Both Algeria and Libya are major exporters of natural gas.

4.2.5 Uranium

Currently uranium is not being produced in the region. However studies show that reserves exist in the NAR as conventional or unconventional and by-product resources. The potentials of the two categories are discussed below.

TABLE 21: MARKETED PRODUCTION OF NATURAL GAS (1000 TOE)

Year	Algeria	Egypt	Libya	Morocco	Tunisia	Total
1971	2448	72	1329	44	1	3894
1973	4120	74	3485	60	115	7854
1975	5866	33	3965	61	212	10137
1977	7071	353	4316	74	232	12046
1979	7973	863	4401	64	333	23634
1981	15485	1844	3248	73	395	21045
1983	24010	2376	3171	71	438	35066
1985	31443	3733	4444	74	412	40106
1987	36012	4714	4145	74	804	45749

* Source Reference [15]

TABLE 22: NATURAL GAS PRODUCTION, CONSUMPTION, RESOURCES AND RESERVES AT END OF 1990 (Billion Cubic Meters)

Country	Production	Consumption	Proved Recoverable Reserves	Estimated Additional Reserves
Algeria	56.63	19.31	3300	510
Egypt	9.21	8.11	351	595
Libya	6.80	4.96	1218	510
Morocco	0.06	-	2	-
Tunisia	0.39	1.53	85	340
Total	73.09	33 91	4956	1955

4.2.5.1 Conventional Type Uranium Deposits

The only country in the region with proved recoverable reserves of conventional type uranium is Algeria. These are estimated to be 26,000 tons of uranium. The estimated cost to recover these reserves at the end of 1990 was less than $ 80/kg [14].

Geological surveys performed in Egypt since 1961 show that there are very small quantities of uranium in the Eastern Desert which are uneconomical to explore. In 1983, the Moroccan uranium reserves were estimated to be between 70 and 180 thousand tons. However, these estimates are highly speculative.

4.2.5.2 Unconventional and by Product Resources

Uranium can be produced as a by-product from marine phosphate in Egypt and Morocco. WEC [14] estimated these resources to be 160,000 tons in Egypt and over 6,000,000 tons in Morocco.

Recovery of uranium from phosphate ores is possible through wet treatment of the ore to produce triple-superphosphate. A plant handling half a million tons of raw phosphate rock per year could theoretically produce 25 tons of U_3O_8 per year at a cost 35-70 US dollars per kg U_3O_8.

The black sands on the beaches of Rosetta and Damieta branches of the Nile contain 0.5-1.0 percent of Monazite. An approximate reserve estimate to a depth of 20 meters is as follows:

Heavy Mineral	60,000,000 Tons
Monazite	6,000,000 Tons
ThO_2	370,000 Tons
U_3O_8	28,000 Tons

However, uranium and/or thorium recovery is presently uneconomical unless it is combined with a large project to recover other minerals.

4.2.6 Hydraulic Energy

The use of hydraulic energy resources to produce mechanical work is one of the oldest forms of energy utilization. Its main attractions are the utilization of a renewable energy resource and low operational cost once the project has been built. The largest present day use of hydraulic energy resources is for electricity production.

With the exception of Libya, all countries of the region possess hydraulic energy resources which are used for electricity production. Table 23 shows that the regional installed capacity is 3.75 GW(e), and the under construction and planned capacities are 0.5 and 1.73 GW(e), respectively.

Annual hydro generation in the region is about 10 TWh which accounts for about 15% of the present regional annual electricity generation. Table 24 shows the development of hydro electricity generation for the various countries in the region.

Algeria is planning to have an additional installed capacity of 100 MW(e). This will yield about 150 GWh/year

TABLE 23: REGIONAL HYDRAULIC POWER GENERATION IN 1990

	Operational		Under Construction		Planned	
Country	Capacity (MW)	Generation (GWh)	Capacity (MW)	Probable Annual Generation (GWh)	Capacity (MW)	Probable Annual Generation (GWh)
Algeria	285	135	-	-	100	150
Egypt	2745	8100	-	-	-	-
Libya	-	-	-	-	-	-
Morocco	646	1220	488	745	1328	2055
Tunisia	77	36	-	-	302	385
Total	3753	9491	488	745	1730	2590

* Source Reference [14]

TABLE 24: DEVELOPMENT OF HYDROELECTRICITY GENERATION (GWh)

Year	Country					Total
	Algeria	Egypt	Libya	Morocco	Tunisia	
1971	330	5041	-	1520	52	6,943
1973	752	5156	-	1192	73	7,173
1975	328	6790	-	1016	32	8,166
1977	269	9037	-	1365	31	10,702
1979	291	9610	-	1582	42	11,525
1981	366	10215	-	1024	30	11.635
1983	235	9817	-	481	29	10,562
1985	646	8663	-	486	104	9,904
1987	499	8658	-	825	113	10,095

* Source Reference [14]

In Egypt additional installed capacity of 427 MW(e) along the River Nile and in Fayum is feasible. Large projects in pumped storage sites and the Qattara depression could provide additional capacities of 4300 and 1800 MW(e), respectively. However, these are not economical at the present time.

In Morocco, the total additional units under construction amount to 488 MW(e). An additional capacity of 1328 MW(e), with annual generation of 2005 GWh is planned.

The installed hydro-power in Tunisia is 77 MW(e). However, it is planned to add 302 MW(e) to the existing capacity.

4.2.7 Peat

Peat is a fossil fuel. It is defined as a mass of organic origin which is passed through a process of transformation and which contains, when completely dehydrated, not less than 50% organic matter. Peatlands do not exist in the region. Therefore, peat is not part of the energy structure in the region.

4.2.8 Wood (Including Charcoal)

Wood, burned directly as firewood or processed into charcoal, is probably the worlds most widely used fuel. In urban areas firewood and charcoal are usually traded commercially. Rural fuel is invariably obtained non-commercially. Table 25 shows the regional forest area and fuel wood production in 1990.

4.2.9 Biomass (Other than Wood)

The potential of biomass as an energy source stems from the fact that the annual photosynthetic storage of energy in the form of biomass is ten fold as much as the used energy from all sources throughout the world. The rural population of the NAR depends upon bio-fuels to meet part of their energy needs. Bio-energy resources include agricultural residues, animal excreta, municipal refuse and sewage sludge. Because of their non-commercial nature bio-energy resources are not readily quantifiable.

TABLE 25: REGIONAL FOREST AREA AND FUEL WOOD PRODUCTION IN 1990

Country	Total Forest Area (Million ha)	Productive Forest Area (Million ha)	Fuel wood (inc. Charcoal) (Million Tons)
Algeria	2 2	1.2	1.378
Egypt	-0.3	-	1.554
Libya	3.6	0.1	0.388
Morocco	0.4	2.3	1.001
Tunisia		0.4	2.234
Total	6 5	4.0	6.555

* Source Reference [14]

Table 26 shows the development of vegetal fuel production. It is clear from the Table that production has increased from about 1.4 MTOE in 1971 to slightly above 2.0 MTOE in 1987. The Egyptian production is about half of the total regional production.

TABLE 26: DEVELOPMENT OF REGIONAL PRODUCTION OF VEGETAL FUEL (MTOE)

	Country					Total
Year	Algeria	Egypt	Libya	Morocco	Tunisia	
1971	264	651	-	-	458	1373
1973	278	681	-	-	475	1437
1975	286	670	-	-	492	1448
1977	298	761	-	-	518	1577
1979	318	788	-	-	544	1640
1981	341	802	-	-	576	1719
1983	341	829	-	-	605	1909
1985	341	938	-	-	650	2078
1987	412	1016	-	-	650	2078

* Source Reference [15]

4.2.10 Solar Energy

The North African Region lies in the solar belt with an annual average insulation ranging from 800 to 1,000 kJ/cm^2. The direct component of solar radiation is 80 to 95 percent of the total on clear days. Sunshine hours are in the range of 3,000-4,000 hours/year.

Small scale projects transforming solar energy into mechanical energy and electricity production have been implemented in various countries in the region. Some of these projects are listed in Table 27.

TABLE 27: SOLAR ENERGY PROJECT LISTING

Country	Site	Application	Technology	Sponsor
Algeria	-	-	-	-
Egypt	Baeisa Village	Communications	PV	-
		Pumping	PV	-
	Sadat City	Communications	PV	World Bank
		Pumping	PV	World Bank
		Lighting	PV	-
		10 kW Power	Thermal	Solar Energy
			Collector	-
Libya	-	-	-	
	-	Refrigeration	-	USAID
Morocco	Bouaboute	Refrigeration	PV	USAID
Tunisia	Bir Amama	Refrigeration	PV	USAID
	Es-Smirat	Refrigeration	PV	USAID
	Hammam Biadha	Pumping	PV	-
		Refrigeration	-	USAID/Tunis.
		Communications		

* Source Reference [16]

4.2.11 Geothermal Energy

There has been little effort to develop geothermal resources in the region. There are numerous thermal springs in the north western and north eastern parts of Algeria. The temperature is above 45 °C in 33% of these springs, reaching 98 °C at Hammam Meskoutine where there is a plant for greenhouse heating. Huge reserves of hot water (50 °C - 56 °C) are present in the Sedimentary Basin of the Low Sahara [14].

The most favorable zones for geothermal exploration in Egypt exist along the border of the Gulf of El Suweis. Hot springs exist along the eastern shore and in Sinai, with surface temperatures as high as 70 °C. There are also numerous thermal springs in the southern and central parts of Tunisia with temperatures rarely exceeding 60 °C. Sedimentary basins containing hot aquifers exist in the southern sectors. There are seven greenhouse heating plants with ratings ranging from 44 kW(t) to 420 kW(t), to utilize these hot aquifers [14].

4.2.12 Wind Energy

Wind energy is plentiful, but diffuse. It was largely displaced as an energy source during the industrial revolution when other sources of cheap and plentiful energy became available. The 1973-74 oil crisis, however, triggered renewed interest in the technology for centralized electricity generation, for water pumping and for power supplies in remote regions. Wind energy was first utilized in the Region by the Ancient Egyptians, some 5000 years ago to pump water, grind grains and operate sailboats in the River Nile. Recent studies showed that wind energy potential is highly favorable in some areas, where wind speeds up to 10 m/s are known to have prevailed. Table 28 shows recorded mean wind speeds for selected locations in Egypt, Libya, Morocco, and Tunisia.

USAID (United States Agency for International Development) has financed the development of a 1 MW(e) wind farm at Ras Ghareb on the Red Sea. The Egyptian Ministry of Defense is also testing a 1 MW(e) wind/diesel system near the Libyan border. Egypt is planning to install about 500 MW(e) of wind power or 5000 machines over the next few years, subject to the results obtained in the current tests, and achieve economic competivety [14].

TABLE 28: AVERAGE ANNUAL WIND SPEEDS IN SELECTED LOCATIONS

Location	Annual Mean Speed (m/s)	Location	Annual Mean Speed (m/s)
Alexandria	3.9	Mostaganem	1.0
Algiers	3.3	Nador	3.7
Bejaia	4.2	Oran	4.0
Benina	5.0	Oujda	3.7
Casablanca	3.5	Owinat	7.0
Dabaa	5.4	Ras El-Hikma	5.0
Dakhla (Morocco)	8.4	Ras Ghareb	7.0
Derna	6.4	Safi	4.0
Errachidia	3.6	Sallum	4.7
Hammam Biadha	3.7	Sidi Barrani	4.9
Haouarin	4.1	Sirt	4.0
Hurghada	6.6	Siwa	3.2
Kharga	4.7	Tahrir	3.2
Laayoune	5.7	Tanger	5.3
Marsa Matrouh	5.3	Tripoli	3.7
Midelt	4.2	Wadi El-Natroun	5.2
Misurata	3.6	Zwara	3.9

4.2.13 Oceanic and Tidal Energy

This renewable energy source has not been investigated in any of the five North African Countries.

4.2.14 Concluding Remarks on the Regional Energy Situation

The only significant basic energy resources in the NAR are crude oil, natural gas, and hydraulic energy, as can be seen in Table 29. Crude oil and natural gas will be depleted in the next century unless new discoveries are made. Hydro power is nearly fully utilized. There is a potential for solar and wind energies but the technology for large scale electricity production is not yet economic. Indigenous uranium resources, at least at economic prices, are very limited.

4.3 ELECTRICITY SUPPLY AND DEMAND

4.3.1 Historical Development

Electric energy was utilized in the NAR as early as 1893 when small diesel engines were installed in Cairo and Alexandria to supply low voltage direct current electricity to some streets and houses. At the moment, the total installed capacity in the NAR is more than 20 GW, as indicated in Table 30.

TABLE 29: SUMMARY OF REGIONAL ENERGY RESOURCES

1 - Coal	With the exception of Morocco, the North African countries import all their needs of coal, which is used mainly in the iron and steel industry. Only part of the Moroccan needs is imported.
2 - Crude Oil	Unless new discoveries are made the present rate of regional production can be sustained for about 30 years.
3 - Oil Shale	Exists, but uneconomical to exploit at present time.
4 - Natural Gas	Proved reserves can sustain current rate of regional production for 68 years.
5 - Uranium	Conventional reserves exist in Algeria (26,000 tons). By-product from phosphate industries can be produced in Egypt and Morocco, but it is uneconomic, unless combined with large scale projects to produce other minerals.
6 - Hydraulic Energy	Nearly fully utilized in the region. Possibility to expand is limited.
7 - Peat	Does not exist in the region.
8 - Wood	Used primarily in rural areas.
9 - Biomass	Insignificant at present time. Not expected to play an important role in the near future.
10 - Solar Energy	Potential exists. Technology not yet economic.
11 - Geothermal Energy	Limited potential
12 - Wind Energy	Potential is limited. Technology still uneconomic.
13 - Oceanic & Tidal Energies	Have not been investigated in the region. Not used commercially in any other country.
14 - Nuclear Energy	Only research reactors exist. Previous attempts to introduce nuclear power plants to the Region were not implemented.

TABLE 30: STATUS OF ELECTRICAL POWER DEVELOPMENT IN THE NORTH AFRICAN COUNTRIES - 1990

Country	Installed Capacity MW	Peak Load MW	Electricity Generation, GWh	Per Capita Demand kWh
Algeria	4745	2742	15,220	645
Egypt	10685	6764	41,420	769
Libya	2417	1695	9,367	2019
Morocco	2028	1580	9,220	351
Tunisia	1343	865	4,938	605
Total	21218	13646	80,165	688

The distribution of installed capacity by type in each NAC, as well as in the Region as a whole, is shown in Table 31. The Table also shows the share of each country in the Regional installed capacity. The evolution of electrical generation over the period (1970-1990) is summarized in Table 32, which was constructed from country inputs [9, 13, 17-19]. These data indicate that electricity generation increased from 12 TWh in 1970 to 80 TWh in 1990 with a mean annual compound growth rate of 10%. The share of hydro-electricity declined from about 50% in 1970 to about 10% of the total electrical generation in 1990.

TABLE 31: DISTRIBUTION OF INSTALLED CAPACITY BY TYPE IN THE NORTH AFRICAN COUNTRIES - 1990

	Share %					
Country	Steam	Gas	Hydro	Diesel	Others	Total
Algeria	41.8	49.0	6.0	2.7	0.5	22.4
Egypt	49.1	24.6	25.4	0.0	0.9	50.4
Libya	69.1	23.7	0.0	7.2	0.0	11.4
Morocco	58.4	6.7	33.3	1.6	0.0	9.5
Tunisia	58.8	36.4	4.8	0.0	0.0	6.3
Total	51.2	29.0	17.6	1.6	0.6	100.0

TABLE 32: EVOLUTION OF ELECTRICITY GENERATION IN THE NORTH AFRICAN REGION

	Demand, GWh					
Year	Algeria	Egypt	Libya	Morocco	Tunisia	Total
1970	2040	6916	454	2006	795	12211
1975	3630	9800	1821	3269	1346	19866
1980	7123	18429	4833	5247	3809	39441
1985	12274	31458	7584	7345	4020	62681
1990	15220	41420	9367	9220	4938	80165

4.3.2 Forecast of Regional Electricity Demand

Although annual peak power demand is the primary determinant of generation plan requirements, annual electrical energy demand should be used as the basic measure of demand level, especially for forecasting purposes.

The formulation of a reasonably reliable method for long range forecast of the likely energy demand is of vital importance. A comprehensive study [20] to develop a long term load expansion plan in Egypt was carried out by Electric Power Systems engineering company (EPS). Six different methodologies presenting various approaches were used in the EPS study. Energy forecasting based on the so-called Sectorial Development Model was identified by EPS as the base approach. In this model, the main electricity consuming sectors were studied separately to forecast the future electrical energy demand for each sector, based on the existing development plans. These sectors are:

- Industry.
- Residential & Governmental.
- Agricultural.
- Public Utilities.
- Governmental Buildings.

Summation of electric energy forecasts for the five sectors provided the projections of the energy sold, from which the total energy generated was calculated. The system losses were assumed to decrease linearly from 16% during the period 1990-1995 to 12% in 2010-2015. The resulting forecasts were extrapolated to the year 2025 using the same technique adopted by EPS.

A similar approach was used by the Tunisian Utility for Electricity and Gas (STEG) to develop a long term expansion plan in Tunisia. Forecast of future electricity demand was based on two methodologies, namely econometric and analytic methods. In the econometric method a correlation was obtained between Gross National Product (GNP) and electricity generation. The analytic method was based upon individual analysis of big consumers of high and medium voltages, statistical analysis of other consumers on medium voltage, and the average annual consumption of low voltage users. STEG predictions of electricity demand in Tunisia [13] indicated that electricity generation will increase from 8.0 TWh in 1998 to 27.7 TWh in 2020, with corresponding peak loads of 1.4 GW and 4.9 GW respectively.

Unfortunately, such a detailed methodology was not clear in the other country inputs. Algeria [17] presented a forecast of electricity generation for which the demand increased annually at a rate of 9.5% in the period 1990-1995 and 5.4% thereafter.

Forecasts of electricity requirements in Libya [18] during the period 1990-2000 indicated an 8% annual rate of increase in electricity generation. It is unlikely, however, that such a high rate will persist until the year 2025. Therefore, for the purpose of the present analysis the annual rate of increase in demand was assumed to be 7% in the period 2000-2010 and 5% in the period 2010-2025.

The Moroccan forecasts [19] indicated that generation will increase from 9 TWh in 1990 to 35 TWh in 2010, with an annual rate of increase of 7%. To extrapolate the forecast up to 2025, annual rates of demand increase were assumed to be 6% and 5% for the periods 2010-2015 and 2015-2025 respectively.

The projections of electricity demand in the NACs, for the period 1990-2025, are presented in Table 33. The Table indicates that the demand in the year 2000 will be almost twice the 1990

TABLE 33: PROJECTIONS OF ELECTRICITY DEMAND IN THE NORTH AFRICAN REGION

	Demand, TWh					
Year	Algeria	Egypt	Libya	Morocco	Tunisia	Total
1995	24.0	60.7	13.8	12.7	6.5	117.7
2000	31.0	79.9	20.2	17.8	9.2	158.1
2005	40.8	99.2	28.4	25.0	12.8	206.2
2010	52.4	119.8	40.0	35.0	17.1	264.1
2015	69.4	145.4	50.8	46.8	22.1	334.5
2020	90.6	165.3	64.8	59.7	27.7	408.1
2025	116.4	188.3	82.7	76.2	33.5	497.1

electricity consumption of 80.1 TWh. By the year 2010, it will be tripled, and by the year 2025 electricity consumption will be almost six times the 1990 consumption.

To illustrate the level of electrification in the NACs, Tables 32 and Table 33 were used to calculate kWh(e) generated/capita. The results are shown in Table 34. Consumption levels shown in Table 34 are very low (except in Libya) and indicate a large potential market. In view of this, the actual future growth rates might be larger than those used in the forecasts.

TABLE 34: PROJECTIONS OF PER CAPITA ELECTRICITY DEMAND IN THE NORTH AFRICAN REGION

	kWh/capita					
Year	Algeria	Egypt	Libya	Morocco	Tunisia	Total
1995	841	1022	2439	428	735	891
2000	986	1218	2965	530	955	1075
2005	1198	1397	3496	696	1232	1293
2010	1380	1559	4170	911	1543	1518
2015	1669	1747	4596	1139	1869	1772
2020	2054	1835	5163	1359	2196	2007
2025	2450	1930	6006	1622	2490	2267

Peak load projections are derived from the energy forecasts and the anticipated load factors using the relationship:

$$\text{Peak Load} = (\text{Energy}) / (8760 \times \text{Load Factor}).$$

Table 35 shows the load factors employed by the North African Countries [9, 13, 17-20]. To estimate the peak load projections up to 2025, the load factors employed by Egypt were linearly extrapolated. For Libya, the load factor was assumed to be 0.61 after the year 2000, which corresponds to the mean value of those employed in 1990 and 2000. For Morocco, a load factor of 0.65 was assumed. Table 36 lists the projected peak loads for the NACs.

TABLE 35: LOAD FACTORS EMPLOYED BY THE NORTH AFRICAN COUNTRIES

	Country				
Year	Algeria	Egypt	Libya	Morocco	Tunisia
1990	0.634	0.699	0.631	-	0.640
1995	0.702	0.666	-	-	0.650
2000	0.694	0.657	0.589	-	0.650
2005	0.684	0.646	-	-	0.650
2010	0.661	0.628	-	-	0.650
2015	0.660	0.625	-	-	0.650
2020	0.651	-	-	-	0.650
2025	0.651	-	-	-	-

TABLE 36: PEAK LOAD PROJECTIONS FOR THE NORTH AFRICAN COUNTRIES

	Demand, MW					
Year	Algeria	Egypt	Libya	Morocco	Tunisia	Regional
1995	3900	10399	2575	2230	1125	20229
2000	5100	13892	3917	3130	1610	27649
2005	6800	17523	5280	4390	2250	36243
2010	9060	21789	7527	6150	3010	47536
2015	11997	26543	9500	8220	3870	60130
2020	15880	30775	12126	10480	4890	74151
2025	20400	35095	15476	13380	5880	90231

The required installed capacities are calculated through the relationship :

Installed Capacity = (1+F) x Peak Load

where F is the ratio of overall reserve capacity to the peak load. Table 37 shows the F values employed by the NACs. The 1990 overall Regional reserve capacity was 55% of the peak load. This excessive reserve capacity in the Region can be attributed to the following reasons:

- The actual increase in electricity consumption in the 1980's was lower than previously foreseen.
- The large share of hydraulic and gas turbines in the Regional installed capacity (46.7%), as can be seen in Table 31.
- Due to obsolescence of some power plants, the actual capacity is less than the nominal installed capacity used to calculate the reserve factor.

TABLE 37: RESERVE FACTORS EMPLOYED BY THE NORTH AFRICAN COUNTRIES

	Country				
Year	Algeria	Egypt	Libya	Morocco	Tunisia
1990	0.73	0.58	0.43	0.28	0.55
1995	0.33	0.41	0.40	(0.25)	0.31
2000	0.22	0.15	0.35	(0.20)	0.28
2005	(0.20)	0.16	(0.30)	(0.20)	0.13
2010	(0.20)	0.21	(0.30)	(0.20)	0.11
2015	(0.20)	0.22	(0.30)	(0.20)	0.12
2020	(0.20)	(0.20)	(0.30)	(0.20)	0.11
2025	(0.20)	(0.20)	(0.30)	(0.20)	0.11

TABLE 38: PROJECTIONS OF REQUIRED INSTALLED CAPACITIES 1990 - 2025

	Demand, MW					
Year	Algeria	Egypt	Libya	Morocco	Tunisia	Regional
1995	5200	14614	3605	2788	1474	27,681
2000	6200	15935	5293	3756	2056	33,240
2005	8160	20314	6865	5268	2550	43,157
2010	10872	26387	9785	7380	3350	57,774
2015	14396	32421	11400	9864	4350	72,431
2020	19056	36930	14551	12576	5450	88,563
2025	4480	42114	18572	16056	6550	107,772

Therefore, it is expected that with long term planning to install steam power plants the reserve capacity will level out to about 20% in most of the NACs. The resulting projections of the required installed capacities are listed in Table 38, which shows that the required regional installed capacity by the year 2025 could be more than 100 GW, i.e. more than 5 times the 1990 installed capacity.

5. REPRESENTATIVE SITES

5.1 GENERAL

The final cost of desalted water provided to the consumer consists of four principal cost components. These are:

- Costs resulting from capital charges.
- Operation and maintenance of the desalination plant.
- Cost of energy provided to the plant.
- Cost related to water storage, transport and distribution to the consumer.

The share of these components in the final water cost depends on many factors, among which are site characteristics. The third of the cost components outlined above is fundamentally a site dependent component and can only be analyzed on a case by case basis [21] .

Construction costs are usually higher in third world countries than the base costs estimated for assumed locations in suppliers' countries. Therefore, it is important in the present study, or indeed in any feasibility study, to have reference or representative sites to estimate the site related costs of the produced potable water.

When a nuclear reactor is used as an energy source for the desalination process, special attention has to be given to the safety aspects and environmental effects of the nuclear plant. This requires among other things detailed site qualification studies, because sites that are adequate for the location of conventional (desalination) plants may not satisfy the requirements for siting a nuclear (desalination) plants. Site related factors can have substantial impact on the cost of the nuclear plant (desalination or other applications).

The main site characteristics and requirements to be considered when siting a nuclear plant are:

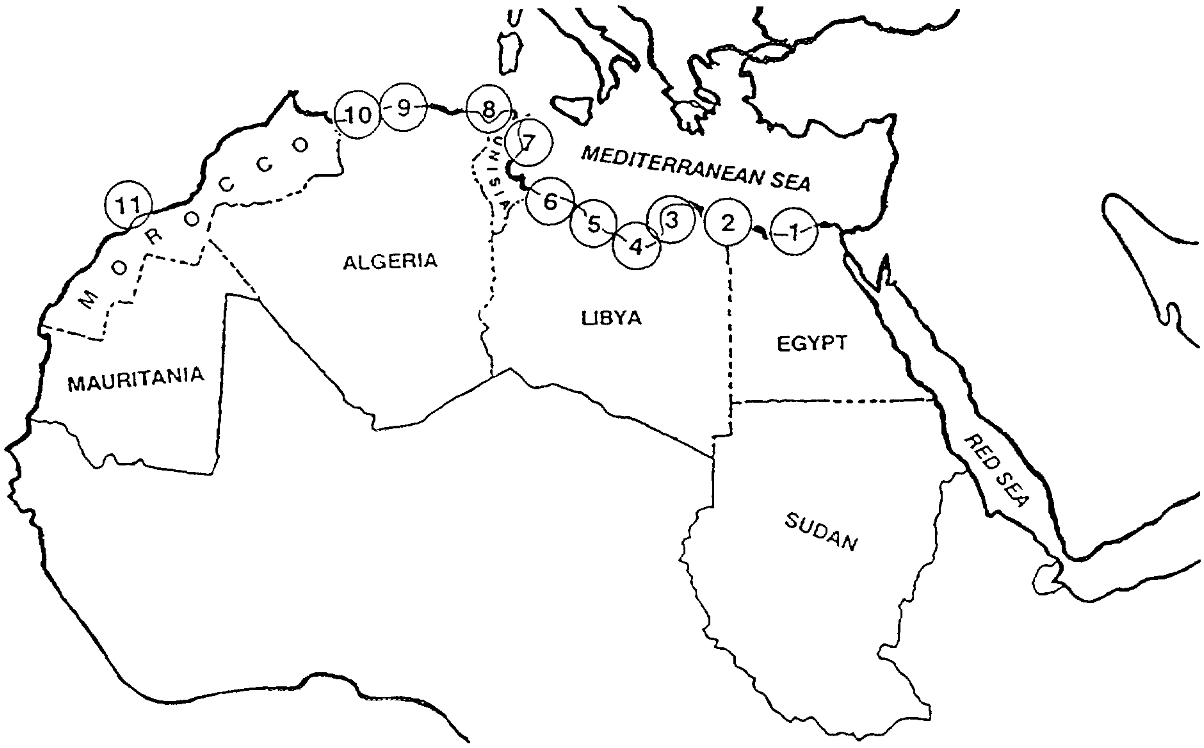
- Engineering characteristics and requirements.
- Safety-related characteristics defining the effects of natural site related phenomena on the plant (e.g. earthquakes, flooding).
- Safety-related characteristics influencing the impact of the plant on the site (e.g. population distribution, dispersion of air and water).
- Environmental effects.

These and other characteristics are discussed in detail in Reference [22].

5.2 SITE SURVEY IN THE NORTH AFRICAN REGION

Eleven possible sites for nuclear desalination plants have been identified in the Region (three of which could be used as composite sites). The selection of these representative sites and the capacities of the required desalination plants have been done by individual NACs outside the scope of the present study, i.e. this is an input from the participating countries, adopted for the purpose of the feasibility study. There has been no attempt to assess this information in any way. Rough estimates of required desalination capacities in these sites were provided in early 1991. However, when the revised data included in this Chapter became available in May 1994, it was not possible to include in the cost comparison which was already underway.

Figure 3 shows the representative sites with the required desalination capacities in the year 2005 as provided by the participating countries in 1991 and 1994. Only four of these sites have been qualified as nuclear sites. These are: El-Dabaa (Egypt), Mostaganem and Oran (Algeria), and Sirt (Libya).



Location	Site	Required Capacity, (1000 m³/d)	
		1991 Data	1994 Data
1	El-Dabaa [1]	240	-
2	Sallum	50	42.6
2	Tobruk	70	40.3
2	Sallum/Tobruk	120	82.9
3	Benghazi	300	198.0
4	Sirt	120	45.0
5	Tripoli [2]	720	400.9
6	Zwara	60	76.4
7	Zarzis [3]	60	13.2
7	Zwara/Zarzis	120	110.2
8	Annaba	60	-
9	Mostaganem	60	-11.2
10	Oran [4]	120	-39.3
10	Mostaganem/Oran	180	-50.5
11	Laayoune[5]	24	1.9

[1] - [5] Sites considered for cost calculations using 1991 data.

Fig. 3: Required desalination capacities in the year 2005 for various North African reference sites

The general description of the sites as well as their population trends and potable water situation are presented below on a country basis. Three of the above sites were identified as possible locations for composite sites to serve the needs of two of the previously identified locations. It might be cheaper to have one "large" plant to serve the needs of two nearby locations (e.g. Sallum and Tobruk), than having two separate smaller plants. The composite sites are also discussed below.

5.2.1 Algerian Sites

5.2.1.1 Mostaganem Site (Cap Ivi)

5.2.1.1.1 General Description

The town of Mostaganem is one of the major towns in the six provinces (Wilayats) that constitute the region Oran. The town is located on the Gulf of Arzew. The site of Cap Ivi near Mostaganem has already been qualified as a nuclear site. Basic meteorological data of the Mostaganem site are presented in Table 39.

TABLE 39: BASIC DATA OF MOSTAGANEM SITE

AIR TEMPERATURE °C			PRECIPITATION mm	SEAWATER TEMPERATURE °C	MAXIMUM WIND SPEED m/s
Max.	Min.	Average			
45.4	0	17.9	400	18.4	30

5.2.1.1.2 Population Trends

The 1990 population was estimated to be 131 thousand. For the future projection it was assumed that population growth rate will be reduced linearly from 3% in 1995 to 1.8% in 2025. The population forecast for Mostaganem is shown in Table 40.

5.2.1.1.3 Potable Water Situation

The drinking water situation in Oran region (including Mostaganem) is reported to be serious. Water is distributed by the Government two or three times per week. However, even this small quantity of water is brackish. The main water supply in the region is provided through dams built to intercept rainwater.

An analysis by the Algerian water authorities indicated that as of 2010 the demand will begin to outstrip the conventional water resources, and will thus require from that time on the commissioning of non-conventional water production facilities (seawater desalination plants) on the Mediterranean shore, e.g. Oran and Mostaganem. Accordingly from that period onward conventional resources will be directed to the communities situated in the interior of the region, while these two centers should then be able to meet their requirements through seawater desalination.

To estimate the water demand, it was assumed that specific water needs for residential and commercial sectors in 1990 is 150 LCD. The future projections were based on the assumption that specific water consumption will increase by 2 LCD annually up to the year 2010, where it will remain constant at 190 LCD until the year 2015. During the period 2015 - 2020 the specific water consumption will increase again by 2 LCD annually to reach 200 LCD by the year 2020 and remain constant thereafter. Industrial water demand was assumed to be 12,000 m^3/d for the period 1990 - 2025.

Distribution losses were assumed to be 35% in 1990 reduced linearly by 0.5% annually to be 30% in 2000. In the period 2000 - 2005, it will be reduced linearly by 1.0% to reach 25% in 2005 and remains constant up to 2015. In the period 2020 - 2025, distribution losses were assumed to be 20%.

Potable water deficit calculations for Mostaganem are summarized in Table 40. The Table shows that a nuclear desalination project to be operational by the year 2015 should have an optimum size of 75,000 m^3/d. To cover future deficit thereafter, a unit size of 5,000 m^3/d would have to be added every five years.

TABLE 40: ESTIMATION OF WATER DEFICIT IN MOSTAGANEM

Year	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	131	153	175	199	223	248	273	298
Specific consumption, LCD	150	160	170	180	190	190	200	200
Resid.& Comm demand, m^3/d	19.650	24.480	29.650	35.820	44.270	47.120	54.600	59.600
Distribution Losses	35%	33%	30%	25%	25%	25%	20%	20%
Required Resid. Supply, m^3/d	30,230	36.540	42,500	47.760	59.020	62.830	68.250	74,500
Required Indust. Supply, m^3/d	12,000	12,000	12.000	12.000	12,000	12,000	12.000	12,000
Other Requirements, m^3/d	0	0	0	0	0	0	0	0
Total Demand, m^3/d	42,230	48,540	54,500	59.800	71.020	74,830	80,250	86,500
Available Resources, m^3/d	41,000	41,000	41.000	71.000	71,000	0	0	0
Deficit, m^3/d	1,230	7,540	13.500	-11,200	20	74,830	80,250	86,500

5.2.1.2 Oran Site (La Macta)

5.2.1.2.1 General Description

The city of Oran is located on the southern Mediterranean coast, 450 km west of Algiers and about 150 km from the Algerian/Moroccan borders (Figure 4). The city is the capital of Wilaya of Oran. The site of La Macta is located in the Gulf of Arzew about 30 km south west of the town of Mostaganem. Both sites are considered well defined sites and have already been qualified as nuclear sites in the framework of nuclear power plant feasibility studies, carried out for the Algerian Government by Sofratom (France) and AECL (Canada) during the period 1976 - 1984.

Figure 5 shows several sites identified as possible locations for nuclear plants in the Gulf of Arzew between Oran (La Macta) and Mostaganem (Cap Ivi). The site studies included: geology, hydrogeology, meteorology, topography, etc. A preliminary water connection study has also been

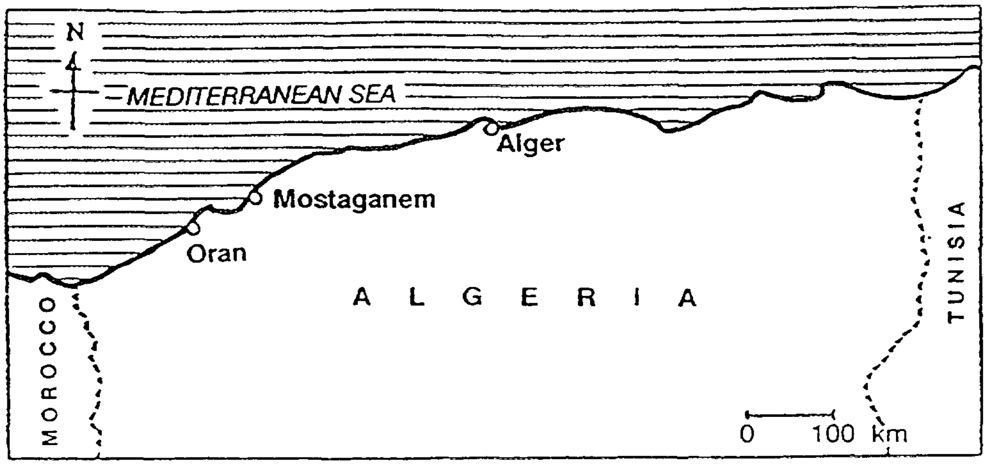


Fig. 4: General map of Nothern Algeria

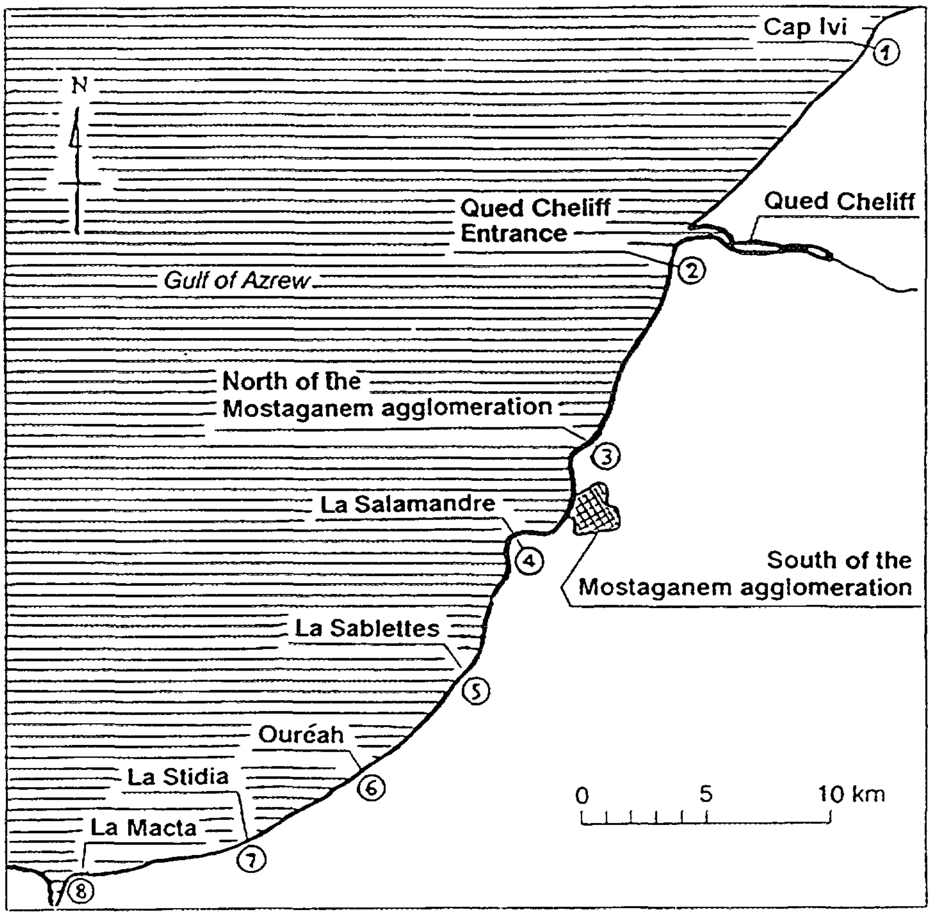


Fig. 5: Possible locations of nuclear plants in La Macta - Cap Ivi area

TABLE 41: BASIC DATA OF ORAN / LA MACTA SITE

AIR TEMPERATURE °C			PRECIPITATION mm	SEAWATER TEMPERATURE °C	MAXIMUM WIND SPEED m/s
Max.	Min.	Average			
43.0	-2.0	17.7	398	14.1	30

TABLE 42: SEAWATER ANALYSIS IN ORAN/LA MACTA SITE

Item	Unit	Station A	Station B
		Surface layer	Surface layer
Temperature	°C	15.3	14.1
C1	%	20.39	20.31
PH	-	8.19	8.24
COD Oh	mg/l	< 0.1	< 0.1
COD Mn	mg/l	1.0	1.0
SS	mg/l	< 0.5	1.0
NH_4-N	mgat/l	1.2	4.1
NO_2-N	mgat/l	0.15	0.32
NO_3-N	mgat/l	0.75	9.31
T-N	mgat/l	9.0	19.0
PO_4-P	mgat/l	< 0.05	< 0.05
T-P	mgat/l	0.21	0.13
SIO_4 - SI	mgat/l	1.7	1.3
Ca	mg/l	412	413
Mg	mg/l	1440	1440
SO_4	mg/l	3210	2990
TDS at 110 °C	mg/l	40000	9400
TDS at 48 °C	mg/l	36000	35900
Electrical Conductivity	mS/cm at 25 °C	55 0	54.8

carried out. This could reduce the costs of constructing a nuclear desalination plant in the future. Basic meteorological data for Oran (La Macta) site is presented in Table 41. Seawater analysis for Oran / La Macta site is shown in Table 42. Most probable sea currents in the Gulf of Azrew are shown in Figure 6.

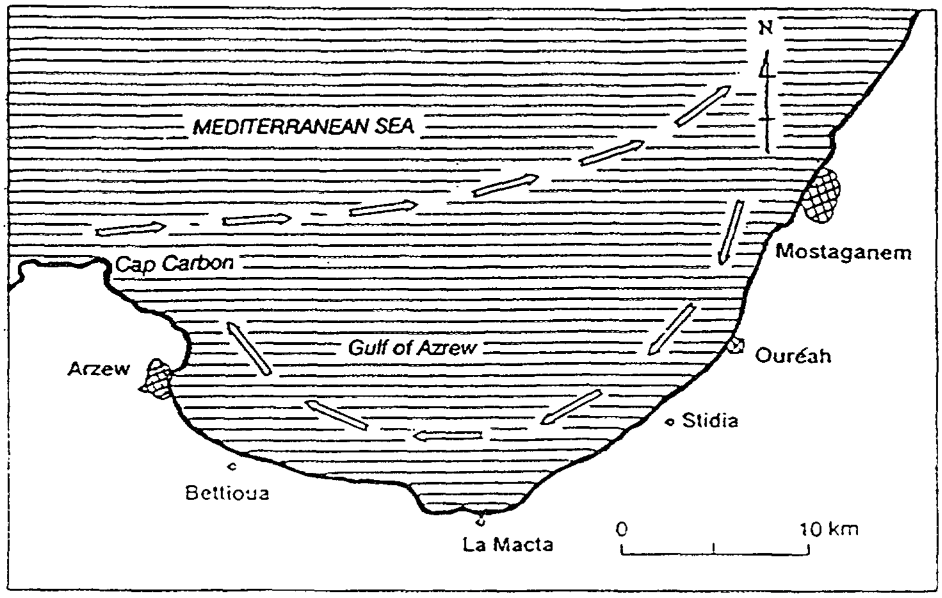


Fig. 6: Prevailing sea currents in the Gulf of Azrew

5.2.1.2.2 Population Trends

The water situation in the city of Oran is similar to that described for Mostaganem (section 5.2.1.1.3). To estimate water demand, the assumptions used for Mostaganem regarding development of specific water consumption and distribution losses were utilized. Industrial water demand was assumed to be 65,000 m^3/d for the period 1990 - 2025.

Potable water deficit calculations for Oran are summarized in Table 43. The Table shows that a nuclear desalination project to be operational by the year 2015 should have an optimum size of 230,000 m^3/d. In the following decade another 110,000 m^3/d should be added.

5.2.2 Egyptian Sites

5.2.2.1 Sallum Site

5.2.2.1.1 General Description

The town of Sallum is one of the seven administrative centers that constitute the Matrouh Governorate which includes the Mediterranean coastal area from west of Alexandria to the Libyan border (Figure 7). Most of the Governorate is an uninhabited desert except for nomadic Bedouins. The majority of the 160,000 permanent inhabitants of the Governorate live on a 500 kilometer long narrow strip along the Mediterranean Coast.

In the last few years the development of tourist facilities along the coast from Alexandria to Marsa Matrouh has undergone a dramatic increase. The initial effects of tourism have been fairly agreeable to most of the resident population.

TABLE 43: ESTIMATION OF WATER DEFICIT IN ORAN

Year	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	1.009	1.127	1,245	1.357	1,464	1.567	1,664	1.764
Specific consumption. LCD	150	160	170	180	190	190	200	200
Resid. & Comm. demand. m^3/d	151,350	180,320	211.650	244.260	278.160	297.730	332,800	352.800
Distribution Losses	35%	33%	30%	25%	25%	25%	20%	20%
Required Resid. Supply, m^3/d	232.846	269.134	302,357	325,680	370.880	396,973	416.000	441,000
Required Indust. Supply. m^3/d	65.000	65.000	65,000	65,000	65,000	65.000	65.000	65.000
Other Requirements. m^3/d	0	0	0	0	0	0	0	0
Total Demand, m^3/d	297.846	334.134	367,357	390.680	435.880	461.973	481.000	506.000
Available Resources, m^3/d	266,000	266,000	375,000	430,000	430,000	232,000	68,000	68.000
Deficit, m^3/d	31,846	68,134	- 7,643	-39,320	5,880	229,973	413,000	438,000

Businessmen, retailers, and service companies are experiencing a large increase in business volume during the summer months. However, adverse effects are also developing and will become more and more severe as tourism increases. The foremost of these problems is the shortage of water during the summer months.

Normal population growth, rapidly increasing number of tourists, and the desire by the Governorate to improve the standard of living, will require a larger and more dependable supply of water to the Governorate. A possible solution would be the installation of a desalination plant in Sallum to serve the area bound by the triangle Siwsa - Sallum - Marsa Matrouh.

Sallum is accessible by train, bus, and car. The coastal highway connecting the five NACs, passes through Sallum. The town is also connected to Alexandria by train. Plans to extend the railways to Tobruk is under way. The nearest civilian airport is in Marsa Matrouh, 200 km to the east. It has two runways crossing each other at right angles. There is also a military base in Sidi Barrrani which is currently being used by travelers arriving from Libya.

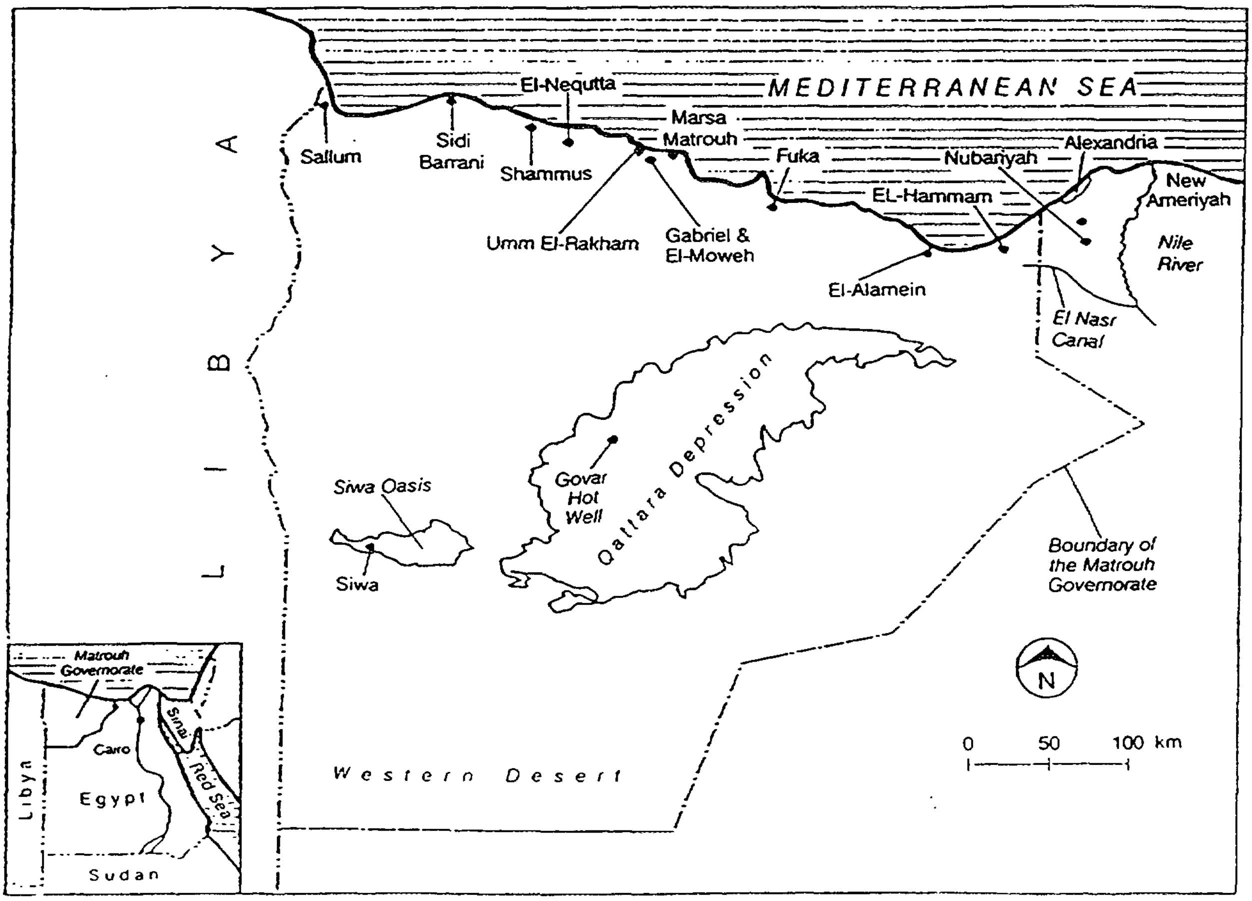
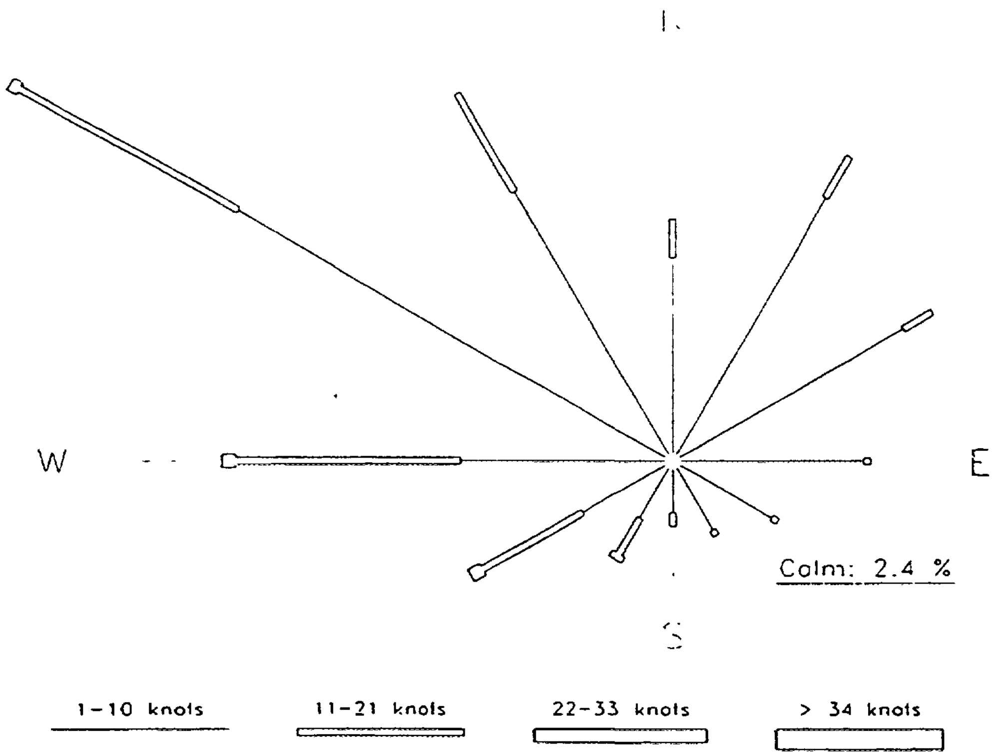


Fig. 7: General map of Matrough Governorate

Basic meteorological data for the town of Sallum is presented in Table 44. Figure 8 shows the distribution of wind velocity and direction in Sallum. The predominant direction of wind is NW. Typical analysis of seawater at Sallum is presented in Table 45

TABLE 44: BASIC DATA OF SALLUM SITE

AIR TEMPERATURE °C			PRECIPITATION mm	SEAWATER TEMPERATURE °C	MAXIMUM WIND SPEED m/s
Max.	Min.	Average			
47.3	3.4	19.5	94.2	16.0	4.7



Joint distribution of wind velocity and direction
(10 m above ground level)

DIRECTIONS	0	30	60	90	120	150	180	210	240	270	300	330	TOTAL
knots												Calms	24
1 - 10	60	89	78	56	33	23	15	19	30	61	147	91	702
11 - 21	11	14	10	2	2	2	4	12	33	67	71	33	261
22 - 33	0	0	0	0	0	0	0	2	4	4	3	0	13
> 34	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	71	103	88	58	35	25	19	33	67	132	221	124	1000

Fig. 8: Annual wind rose at Sallum (1964 - 1980)

TABLE 45: TYPICAL ANALYSIS OF SEAWATER AT SALLUM

PH	7.94
Total suspended solids (g/L)	0.14
Anion (g/L)	
HCO_3	0 19
SO_4	3.09
Cl	21 68
Cation (g/L)	
Ca^{++}	0.17
Mg^{++}	1 44
Na^{+}	12.36
K^{+}	0.45
Fe^{++}	0.0001
Total dissolved solids (mg/L)	42,170

5.2.2.1.2 Population Trends

In 1990, the total population of the Matrouh Governorate was estimated to be about 180,000 people, based on average growth rate of 3.4%. The population of each of the seven administrative centers of the Governorate is shown in Table 46.

The study area stretches across four administrative centers. These are: Marsa Matrouh, Sallum, Sidi Barrani and Siwa. It is clear from Table 46 that closing the Egyptian / Libyan borders had a devastating effect on Sallum, where some of the residents had to migrate to other towns. With the re-opening of the borders between the two countries, it is expected that the population of Sallum and Sidi Barrani will increase at a higher rate than shown in Table 46.

For areas West and South of Marsa Matrouh, future population was estimated based on a growth rate of 3% for major urban areas and 2% for rural areas. For the city of Marsa Matrouh, the projected resident population, which comprises these people who live there on a permanent basis, was based on the 1988 resident population of 61,000 people and an annual growth rate of 3.5%.

Population forecast for the area to be served by the desalination plant in Sallum is included in Table 47. The Table does not include transient population, i.e. those people who live in the study area for varying lengths of time during summer months. These are people who temporarily live with relatives, who live in dwelling units that are occupied only in the summer, who are guests of hotels, and those living in summer camps.

TABLE 46: POPULATION DISTRIBUTION OF MATROUH GOVERNORATE

Administrative Centers	1976 Census	1986 Census	Average Annual Growth Rate
Burrg El-Arab	10,793	17,345	4.86%
El-Dabaa	10,428	18,418	5.85%
El-Hammam	12,242	13,272	0.81%
Marsa Matrouh	49,136	67,310	3.20%
Sallum	6,304	5,640	-1.10%
Sidi Barrani	16,997	19,291	1.27%
Siwa	6,872	9,842	3.66%
Total	112,772	157,118	3.37%

5.2.2.1.3 Potable Water Situation

In a recent study by CH2M HILL et al [23, 24] to assess water and waste water needs for Matrouh Governorate, field surveys were conducted to determine existing conditions within the Governorate. These surveys included:

- Land Use Survey.
- Occupancy Survey.
- Household Survey.
- Private Establishment Survey.
- Hotel Survey.
- Village Survey.

In addition, information was obtained from secondary sources that included local and central governmental agencies, private companies and knowledgeable people. The city of Marsa Matrouh has six principal water supply components which consist of one non-potable and five potable components. These components are:

a) Non - Potable

- Horizontal Brackish Water Wells

b) Potable

- Alexandria Water General Authority (AWGA) pipeline system.
- Seawater desalination plant.
- Brackish water desalination plant.
- Water Train.
- Private Trucks.

The CH2M HILL International et al Study [23], indicated that the total potable water supply of the city in 1987 was 2100 m^3/d in Winter and 2800 m^3/d in Summer.

Regions West and South of the City of Marsa Matrouh obtain water from a variety of independent supply systems including desalination plants, water train, stored rainwater, and brackish water from wells. Interviews with local officials indicated that rainwater collection in cisterns and brackish water wells are the principal water supply sources in these areas. Siwa receives most of its water from several brackish wells with artisan pressure. Sidi Barrani and Sallum use rainwater runoff collection to a large degree, in addition to supplemental brackish water sources. Distribution of water to consumers in these areas is generally by some method of hauling the water from the source to the home or establishment. Hauling methods include water trucks and wagons, donkey-cart, and hand-carried containers

In 1988, the specific water consumption for the City of Marsa Matrouh was estimated to be 27 LCD in winter and 42 LCD in summer [23, 25]. These low consumption rates were attributed to seasonal shortages of water and lack of modern conveniences such as washing machines and dishwashers. Hotels were found to be significant consumers of water, and they have highly variable seasonal demand. During the summer, three star hotels consume 300 LCD, and the other hotels consume 190 LCD.

Formulation of water consumption rates used to plan development for the present study are based on existing water consumption rates of various user categories and a projected increase in consumption rates according to a reasonable development schedule. An average growth rate in water consumption of 4 LCD per year was considered reasonable for urban areas. Increasing demand for water by rural residents is expected to be more gradual than assumed for urban. Transient population was estimated to be 60% of the population in 1990 and gradually reduces to be 40% of the population in 2025.

Table 47 shows a summary of the water deficit calculations. Touristic demand is included under "Other requirements". Distribution losses were assumed to be 30% in the period 1990-2000, reduced to 25% in the period 2000-2010. Finally, distribution losses were assumed to be 20% in the period 2010-2025. Industrial water supply requirements were assumed to increase linearly by 1000 m^3/d per year to reach a constant value of 10,000 m^3/d in the year 2010. Available resources were increased in 1995 to account for the new Ameriyah and Northwest coast water supply system that is scheduled to be operational by 1995. As more tourist villages are constructed east of Marsa Matrouh, more water will be extracted from the pipeline. Thus, less supply will be available at the City of Marsa Matrouh. This has been taken care of by assuming a linear decrease in the available resources by 100 m^3/d per year.

TABLE 47: ESTIMATION OF WATER DEFICIT IN SALLUM AREA

Year	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	117	136	158	185	216	253	296	346
Specific consumption, LCD	46	66	86	106	126	146	166	186
Resid & Comm demand, m^3/d	5,400	9,000	13,600	19,700	27,300	37,000	49,200	64,500
Distribution Losses	30%	30%	30%	25%	25%	20%	20%	20%
Required Resid Supply, m^3/d	7,700	12,900	19,400	26,300	36,400	46,300	61,500	80,600
Required Indust Supply, m^3/d	0	5,000	10,000	10,000	10,000	10,000	10,000	10,000
Other Requirements, m^3/d	4,600	7,300	10,400	13,300	17,500	20,900	26,100	32,000
Total Demand, m^3/d	12,300	25,200	39,800	49,600	63,900	77,100	97,600	112,600
Available Resources, m^3/d	6,500	8,000	7,500	7,000	6,500	6,000	5,500	5,000
Deficit, m^3 /d	5,800	17,200	32,300	42,600	57,400	71,100	92,100	107,600

5.2.3 Libyan Sites

Libya is the only country in the Region suffering from overall water deficit. The large population centers are located on the Mediterranean Coast. All of these population centers are facing a shortage of potable water. Five major centers were identified as representative sites. These are: Benghazi, Sirt, Tobruk, Tripoli and Zwara. Because population and potable water projections in these sites were based on the same average parameters, they will not be treated separately in the following sections except for the general description.

5.2.3.1 General Description

Benghazi

Benghazi is the second largest city in Libya, preceded only by the capital Tripoli. It is the largest city in the eastern part of Libya. The city is about 500 km west of the Egyptian/Libyan border. (see Figure 9). It is accessible by air, sea and land. The coastal highway connecting the five NACs passes through the city, which has a modern transportation system that includes trains, buses and motorways.

Sirt

Sirt is located on the Gulf of Sirt (Figure 9), 465 km east of Tripoli and 565 km west of Benghazi. Until the discovery of oil in Libya, Sirt had little importance. It was one of the few coastal settlements, between Benghazi and Misratah, that served as a trading post, as well as a market center for the surrounding hinterland.

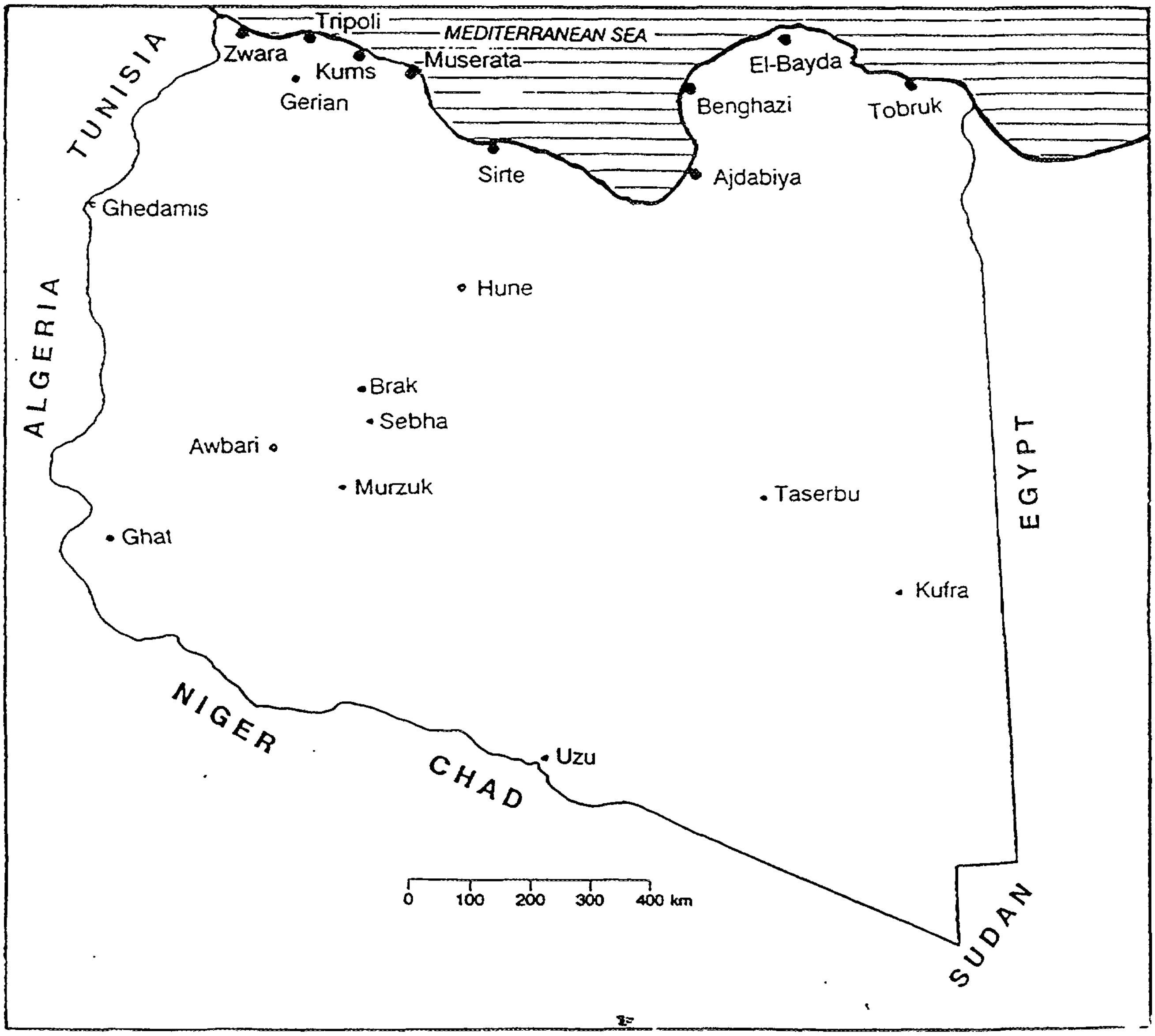


Fig. 9: General map of Libya

In the regional plan it is recommended to strengthen the role of Sirt as a market for agricultural products. It is also planned that the town will become the administrative center for all Libya, as well as becoming, with its satellite Zaafran, a major industrial center. Sirt has a civil airport, but has no harbor up to date.

Tobruk

Tobruk is located on the Mediterranean Coast, 100 km west of the Egyptian/Libyan borders. The town has a perfectly natural harbor within which lies the port of Tobruk. The port was seriously damaged during World War II and many ship wrecks still lie in the bay. The potential of the port and its distance from the major port of Benghazi justify the expectation that it will be the only other worthwhile general port East of Libya. At present, there is no airport for civil aviation in the town. The previous military base in El-Adem is temporarily used to serve domestic flights.

The combination of the above favorable factors warrants the expectation that Tobruk may develop a certain amount of industry. There is also a rather unexpected tourist role for the town, occasioned by the existence of a war battlefield and cemeteries in the immediate surroundings, which are visited by the relatives of the buried soldiers.

Tripoli

Tripoli has the largest concentration of population and economic activities in the country. Tripoli is the capital of Libya, where 27% of the Libyan population resides. It is 170 km east of the Tunisian/Libyan borders (Figure 9).

The city has a modern transportation infrastructure which includes modern highways, trains, harbor and airport. The city is connected to the electrical grid of the Tripoli Region. Forecasts of future electrical demand indicate that it might be 5-6 times the 1990 demand by the turn of the century.

Tripoli and its satellite towns constitute the so called Tripoli Agglomeration. The scale of socio-economic development of the agglomeration will necessitate further development of transport system, water supply system, sewerage and storm water drainage systems, electric power supply, gas supply, and telecommunication.

Zwara

Zwara is located on the coast area in the North-Western part of Tripoli Region (see Figure 9). It is 110 km west of Tripoli and 60 km east of the Libyan / Tunisian borders. Agriculture is the major activity for the population. More than 1500 hectares are planted with fruits, olives and grains. Recently, heavy industries were introduced to the area through construction of a petro-chemical complex in Abukamash to utilize the available natural resources. It is also planned to construct a large aluminum complex in the area.

Zwara has a good electric network that is supplied through a 45 MW power station and the Tripoli Region electric grid. The town is accessible by land. The coastal highway connecting the five NACs passes through the town center. Basic meteorological data and seawater analysis at the different sites are shown in Tables 48 and Table 49 respectively.

5.2.3.2 Population Trends

The 1984 census indicated that the total Libyan population was about 3.6 million, consisting of 3.2 million Libyan nationals and 0.4 million foreigners. Future growth rates are expected to decrease gradually as shown in Figure 10. To estimate the future population in the representative sites, the overall growth rates were applied to 1984 population of these sites [11]. The corresponding population projections are shown in Tables 50 - 54.

TABLE 48: BASIC DATA OF THE LIBYAN SITES

	Air Temperature, °C			Precipitation mm	Seawater Temperature °C	Maximum Wind Speed m/s
Site	Max	Min	Average			
Benghazi	-	-	-	-	-	-
Sirt	41	2	-	180	-	-
Tobruk	26	11	-	101	-	-
Tripoli	28	12	-	250	-	-
Zwara	27	12	19.4	238	-	-

TABLE 49: ANALYSIS OF SEAWATER AT DIFFERENT LIBYAN SITES

Site/ Analysis	Zwara	Tripoli	Sirt	Benghazi	Tobruk
Ca^{++} (ppm)	-	455	-	-	451
Mg^{++} (ppm)	-	1427	-	-	1375
Cl^{-} (ppm)	-	20987	-	-	20672
SO_4 (ppm)	-	2915	-	-	3065
Na^{+} (ppm)	-	11600	-	-	11406
HCO (ppm)	-	163	-	-	162.5
K^{+} (ppm)	-	419	-	-	426
TDS (ppm)	-	37968	-	-	38000
PH	-	8.0	-	-	-

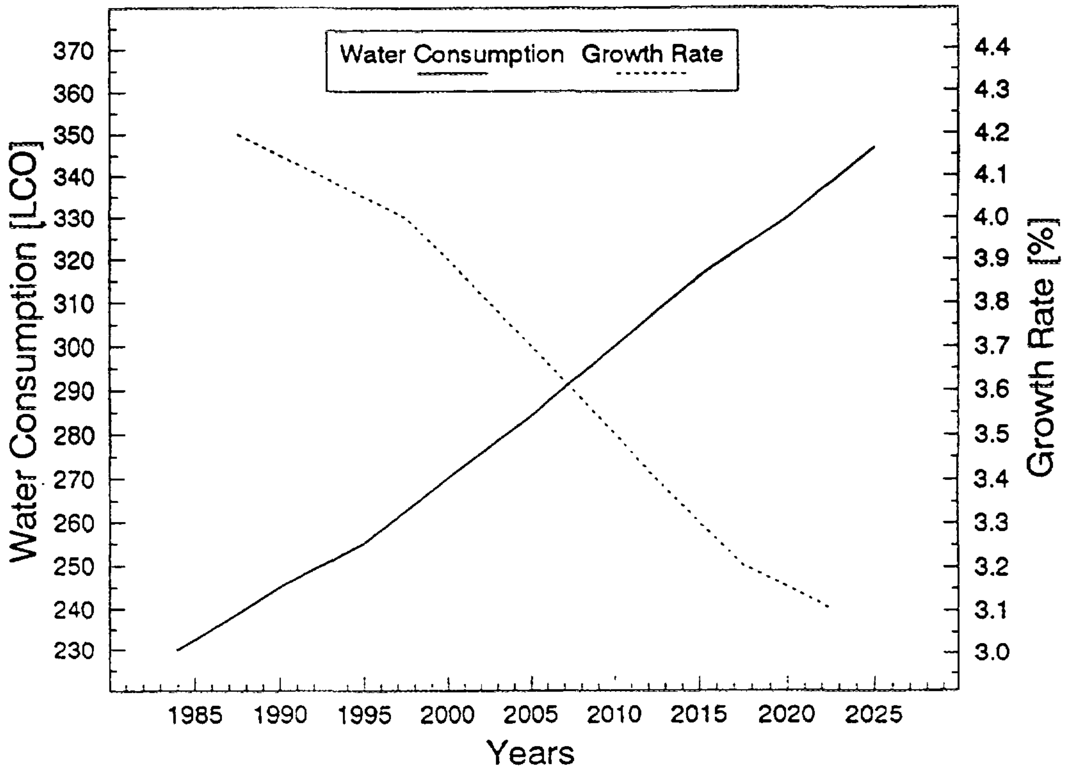


Fig. 10: Projected population growth rate and specific water consumption in Libya

TABLE 50: ESTIMATION OF WATER DEFICIT IN BENGHAZI

Year	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	621	755	909	1084	1280	1475	1675	1837
Specific consumption, LCD	180	188	195	220	232	248	264	280
Resid. & Comm demand, m^3/d	111,832	141,594	177,278	238,471	296,471	365,752	442,123	514,468
Distribution Losses	25%	25%	25%	20%	20%	20%	20%	20%
Required Resid. Supply, m^3/d	149,109	188,792	236,370	298,089	371,206	457,190	552,654	643,085
Required Indust Supply, m^3/d	27,048	36,323	48,219	64,924	86,305	116,446	154,245	206,945
Other Requirements, m^3/d	0	0	0	0	0	0	0	0
Total Demand, m^3/d	176,157	225,115	284,589	363,013	457,511	573,636	706,899	850,030
Available Resources, m^3/d	165,000	165,000	165,000	165,000	165,000	165,000	165,000	165,000
Deficit, m^3/d	11,157	60,115	119,589	198,013	292,511	408,636	541,899	685,030

TABLE 51: ESTIMATION OF WATER DEFICIT IN SIRT

	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	142	173	208	248	293	337	383	420
Specific consumption, LCD	180	188	195	220	232	248	264	280
Resid. & Comm. demand, m^3/d	25,572	32,379	40,539	54,539	67,908	83,638	101,102	117,646
Distribution Losses	25%	25%	25%	20%	20%	20%	20%	20%
Required Resid. Supply, m^3/d	34,097	43,172	54,052	68,165	84,885	104,548	126,378	147,057
Required Indust. Supply, m^3/d	6,185	8,306	11,027	14,846	19,735	26,628	35,272	47,323
Other Requirements, m^3/d	0	0	0	0	0	0	0	0
Total Demand, m^3/d	40,282	51,478	65,079	83,011	104,462	131,176	161,176	194,380
Available Resources, m^3/d	38,000	38,000	38,000	38,000	38,000	38,0000	38,000	38,000
Deficit, m^3/d	2,282	13,478	27,079	45,011	66,462	93,176	123,650	156,380

TABLE 52: ESTIMATION OF WATER DEFICIT IN TOBRUK

Year	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	120	146	176	210	248	286	324	356
Specific consumption, LCD	180	188	195	220	232	248	264	280
Resid. & Comm. demand, m^3/d	21,659	27,422	34,334	46,185	57,514	70,836	85,626	99,638
Distribution Losses	25%	25%	25%	20%	20%	20%	20%	20%
Required Resid. Supply, m^3/d	28,878	36,563	45,778	57,731	71,892	88,545	107,033	124,547
Required Indust. Supply, m^3/d	5,238	7,035	9,339	12,574	16,715	22,552	29,873	40,079
Other Requirements, m^3/d	0	0	0	0	0	0	0	0
Total Demand, m^3/d	34,402	43,598	55,117	70,305	88,607	111,097	136,906	164,626
Available Resources, m^3/d	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Deficit, m^3/d	10,402	19,598	31,117	46,305	64,607	87,097	112,906	140,626

TABLE 53: ESTIMATION OF WATER DEFICIT IN TRIPOLI

Year	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	1268	1541	1856	2212	2613	3010	3418	3750
Specific consumption, LCD	180	188	195	220	232	248	264	280
Resid. & Comm. demand, m^3/d	228,255	289,002	361,835	486,733	606,123	746,521	902,398	1,050,058
Distribution Losses	25%	25%	25%	20%	20%	20%	20%	20%
Required Resid Supply, m^3/d	304,340	385,336	482,446	608,416	757,654	933,151	1,127,998	1,312,572
Required Indust. Supply, m^3/d	55,207	74,126	98,419	132,503	176,155	237,708	314,824	422,386
Other Requirements, m^3/d	0	0	0	0	0	0	0	0
Total Demand, m^3/d	359,547	459,462	580,865	740,919	933,809	1,170,859	1,442,822	1,734,958
Available Resources, m^3/d	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000
Deficit, m^3/d	59,547	159,462	280,865	440,919	633,809	870,859	1,502,822	1,794,958

TABLE 54: ESTIMATION OF WATER DEFICIT IN ZWARA

Year	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	232	283	340	406	479	552	627	687
Specific consumption, LCD	180	188	195	220	232	248	264	280
Resid. & Comm. demand, m^3/d	41,837	52,970	66,320	89,212	111,095	136,828	165,399	192,463
Distribution Losses	25%	25%	25%	20%	20%	20%	20%	20%
Required Resid. Supply, m^3/d	55,782	70,627	88,426	111,515	138,869	171,035	206,749	240,579
Required Indust. Supply, m^3/d	10,119	13,655	18,039	24,880	32,287	43,563	57,704	77,418
Other Requirements, m^3/d	0	0	0	0	0	0	0	0
Total Demand, m^3/d	65,901	84,282	106,465	136,395	171,156	214,598	264,453	317,997
Available Resources, m^3/d	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Deficit, m^3/d	60,901	69,282	91,465	121,395	116,156	199,598	249,453	202,997

5.2.3.3 Potable Water Situation

Most of the present water supply in the above cities depends on ground-water and desalination plants. Due to over-exploitation of the coastal aquifers to face the present deficit in water supply the following problems developed:

- Continuous lowering of the ground water table.
- Exhaustion of several fresh water aquifers.
- Deterioration of ground water quality.
- Seawater intrusion.

In order to estimate domestic water demand, the average specific water consumption including losses of 230 LCD for the year 1984 was considered to be representative for the whole population [7, 11]. An annual rate of increase in the specific consumption was used in the period 1984 - 2025. Distribution losses were assumed to be 25% in the period 1990 - 2000, and 20% in the period 2000 - 2025.

The water supply for industrial purposes was estimated in 1985 to be 55 Mm^3/y. The Libyan future industrial water demand was estimated based on the assumption of 6% annual growth rate [7]. The corresponding specific industrial water consumption were calculated using the projected population indicated in Table 3. These varied from 44 LCD in 1990 to 112 LCD in 2025, and were used to estimate industrial water demand for each of the five representative sites.

The projected water deficits for the Libyan sites are shown in Tables 50 - 54. The required desalination capacities in the year 2015 for these sites varies from 80,000 m^3/d in Tobruk to more than 800,000 m^3/d in Tripoli.

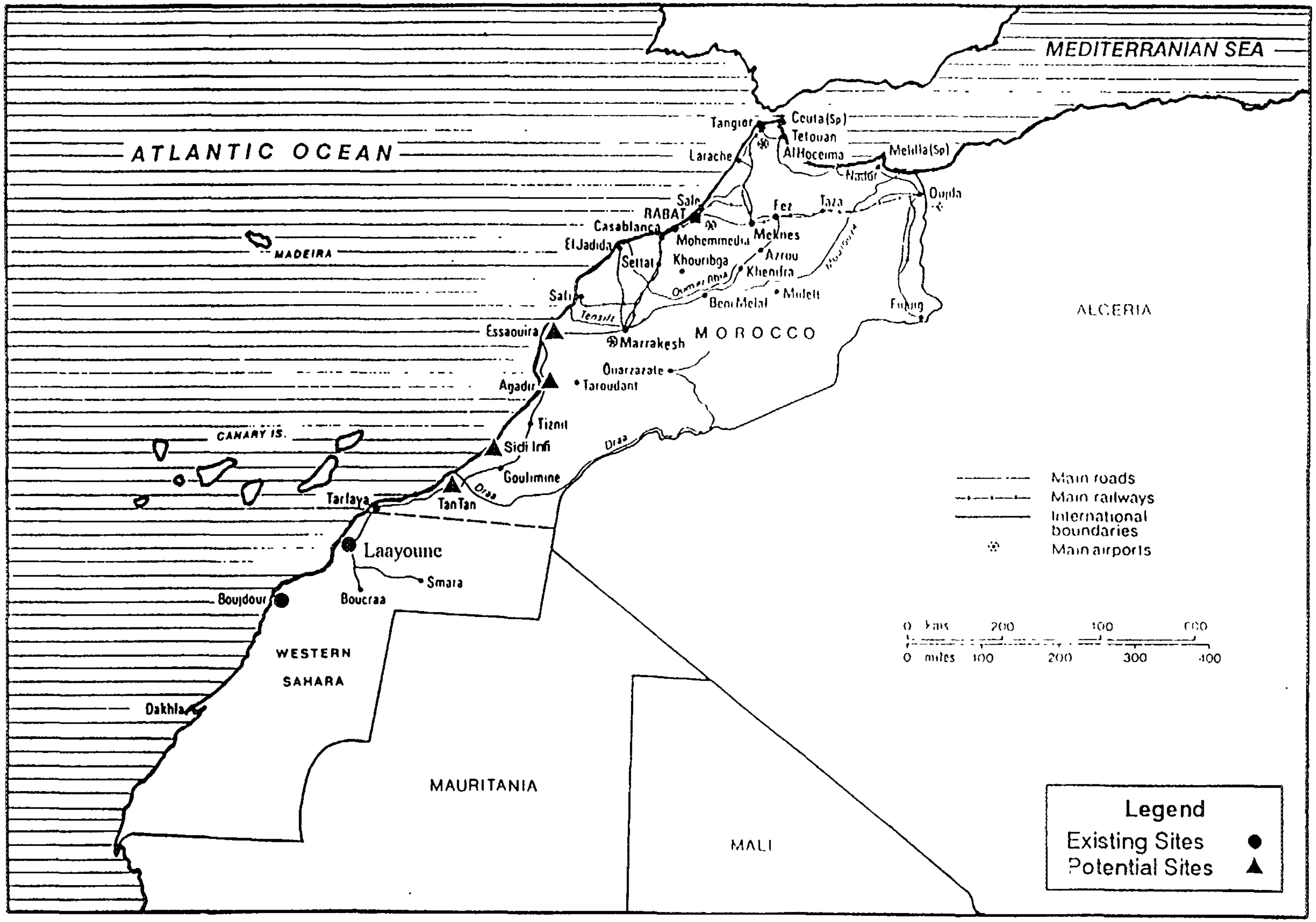


Fig. 11: General map of Morroco

5.2.4 Moroccan Sites

5.2.4.1 Laayoune Site

5.2.4.1.1 General Description

Laayoune is the largest city of the Sahara Region (Figure 11). It is located on the Atlantic coast. The town has three diesel units to generate electricity with a total installed capacity of 21 MW. The estimated growth in electricity demand in the Sahara Region is estimated to be 6.5% per year up to the year 2005 and 8% per year after that.

5.2.4.1.2 Population Trends

In 1990 Laayoune population was estimated to be 120,000 people. For the future projections, it was assumed that the population growth rate will be 2.85% in the period up to 2005 and reduced to 2.6% afterwards. The resulting population forecast is shown in Table 55.

5.2.4.1.3 Potable Water Situation

Specific water consumption in Laayoune is very low. In 1990, it was estimated to be 31 LCD. The available ground water resources are estimated to be about 5600 m^3/d. The balance between demand and supply is made through water transportation by trucks. Currently, a 7000 m^3/d RO desalination plant is under construction.

To estimate future water demand, the specific water consumption was assumed to be 45 LCD for non-connected population to the public water system, 15.3 LCD for administrative uses and 4.1 LCD for industrial uses. The population connected to the public water system was 60% in 1990 and are expected to reach 90% of the total population in Laayoune by 2025. Provisions were also made for peak loads. The results of water demand for various sectors are shown in Table 55. It is clear from the Table that there will be a surplus of water up to the year 2000. A deficit will then develop, and increase from about 2000 m^3/d in 2005 to about 15,000 m^3/d in 2025.

TABLE 55: ESTIMATION OF WATER DEFICIT IN LAAYOUNE

Year	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	120.3	138.3	159.0	182.9	208.1	237.0	269.8	305.7
Specific consumption, LCD	31	31	35	35	38	38	40	42
Resid. & Comm. demand, m3/d	3,700	4,300	5,500	6,300	7,900	9,000	10,700	12,700
Distribution Losses	14	14	13	13	11	11	11	11
Required Resid. Supply, m3/d	4,300	5,000	6,300	7,200	8,900	10,100	12,000	14,300
Required Indust. Supply, m3/d	600	650	750	850	950	1,100	1,250	1,400
Other Requirements, m3/d	1,800	4,350	5,150	6,450	7,350	8,600	9,550	11,800
Total Demand, m3/d	6,700	10,000	12,200	14,500	17,200	19,800	22,800	27,500
Available Resources, m3/d	1,700	12,600	12,600	12,600	12,600	12,600	12,600	12,600
Deficit, m3/d	1,100	- 2,600	- 400	1,900	4,600	7,200	10,200	14,900

*This value is the amount of fresh water distributed by mobile tanks.
The existing network is supplied by brackish water (5,200 m^3/d; TDS≅3,000 ppm).
From 1995 the network will be supplied totally fresh water

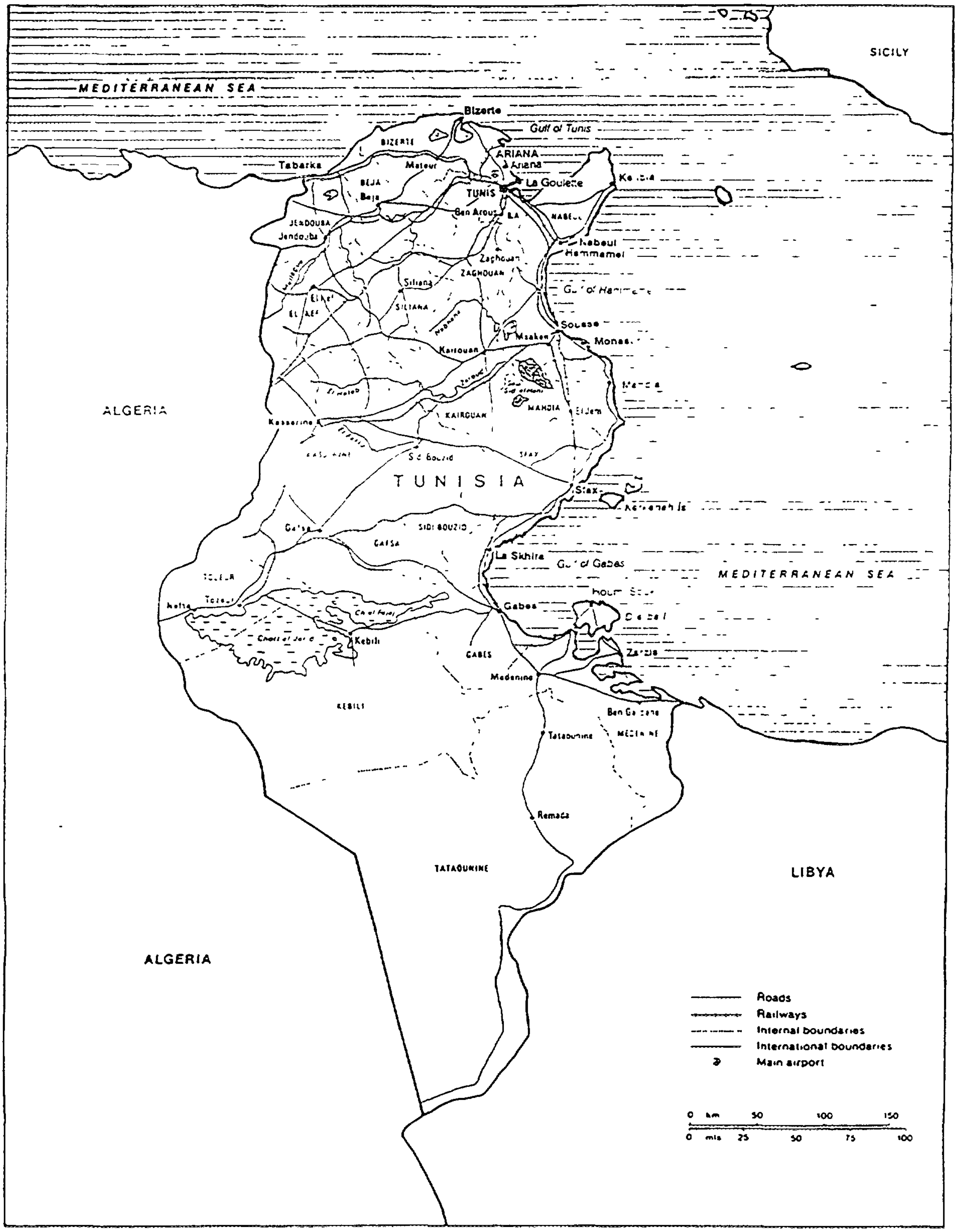


Fig. 12: General map of Tunisia

5.2.5 Tunisian Sites

5.2.5.1 Zarzis Site (South Tunisia)

5.2.5.1.1 General Description

Zarzis is an international commercial port with good facilities. It is located in the South of Tunisia near the Libyan border on the Mediterranean Coast. The area of South Tunisia, which is a well established tourist location, consists of the Governorates of Medinine and Tataouine, as well as the Region of Mareth and Gabes including the city of Gabes, El Hamma, Methouia and Ouedhref, as shown in Figure 12. Further development of tourism is limited by water availability and electric power supply reliability.

The proposed site is located 29 km south East of Zarzis in the large plateau on the edge of Wadi Alwane. The site is gently flattened and sloped down to the sea. The shore is formed by cliffs of about 2-6 meters high. The access to the site is possible from the main coastal highway connecting the five NACs. At the moment, the train terminates in Gabes. However, plans to extend the railways to Libya are being carried out. The nearest airport is the international airport at Jerba. There is also a small airport with limited traffic in Gabes.

The great tourist potential of the region has developed an expanding tourist industry. The main tourist attractions are in Jerba and Gabes. Industrial activities are concentrated in Ghannouch. The main industries in the area are: chemical, mechanical and electrical industries. Limited agricultural activities also exist in the region. Geological studies [26] indicated the existence of a fault NW-SW passing in the axis of Bhiret El Bibane. This fault should be studied further during site qualification. Seawater salinity at the site ranges from 37,500 to 39,250 ppm. Basic meteorological data related to the Zarzis site is presented in Table 56.

TABLE 56: BASIC DATA OF ZARZIS SITE

AIR TEMPERATURE ^0C			PRECIPITATION mm	SEAWATER TEMPERATURE ^0C	MAXIMUM WIND SPEED m/s
Max.	Min.	Average			
48.0	-1.0	24.7	213.0	19.8	4.2

5.2.5.1.2 Population Trends

Connected population forecast for the Area of South Tunisia (i.e. the area to be served by the desalination plant in Zarzis) was presented in References [26]. The future population forecast, as provided by Tunisian authorities, is indicated in Table 57.

5.2.5.1.3 Potable Water Situation

Present water supply in Medenine and Tataouine Governorates is ensured by means of common water distribution system known as the South Tunisia Network. The basic source of water in the area is groundwater extracted from the aquifers of Zeuss-Koutine, Medenine, Tataouine and Gabes. These aquifers produce about 47,828 m^3/d with salinity ranging between 2000 and 3500 ppm. For Gabes region, water supply is ensured essentially by means of a 1000 mm diameter pipe which transfer underground water from Chott El Fejjej aquifers. The water at 70 ^0C temperature and 3000 ppm salinity is passed through an air cooler before being pumped to different cities in the Gabes region. Also some local resources are used to reinforce Gabes region water supply. The total resources actually mobilized in this region are about 52.457 m^3/d as average.

In order to improve water quality and reinforce resources in the region (2000 ppm in Medenine and Tataouine Governorates and 1500 ppm in Gabes region) a brackish water reserve osmosis desalination plant with a capacity of 22,500 m^3/d will be soon operational in Gabes. This capacity will reach 30,000 m^3/d in 1998. Gabes desalination plant at 65% recovery rate has the feed flow ensured by Chott El Fejjej resources. For Medenine and Tataounie Governorates, tender documents for brackish water reverse osmosis desalination plant have already been sent to the lenders for approval. At the end of year 1999, additional brackish water desalination capacity of 24,000 m^3/d, will be operational in Jerba and Zarzis. For these desalination plants, feed will be ensured by brackish resources from Mio-Pliocene aquifer at 6000 ppm salinity.

This total resources were 98,126 m^3/d in 1990, 91,646 m^3/d in 1995 and will be 105,902 m^3/d in year 2000 assuming that the daily peak factor in south Tunisia is about 1.4.

To estimate the water demand, it was assumed that the residential specific water consumption of 67 LCD in 1990 will be increased at a rate of 3 LCD every five years. Other requirements, including tourist demand, were assumed to increase from 9,000 m^3/d in 1990 to 45.545 m^3/d in 2025. In the deficit evaluation, industrial water requirement in Gabes region is not included. However, some of the resources coming from Chott El Fejjej aquifer are allocated to industrial uses and suppose this resource will suffice until 2025.

The projected water demand for South Tunisia and the corresponding deficit are summarized in Table 57. It should be mentioned, however, that the salinity of the available resources (2000 - 3500 ppm) is well above that recommended by the WHO standards. Therefore, the real deficit is much higher than that depicted in Table 57, if the WHO standards water is to be provided to the population.

TABLE 57: ESTIMATION OF WATER DEFICIT IN ZARZIS AREA (SOUTH TUNISIA)

Year	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	603.5	694.1	797.6	914.3	1048.1	1185.9	1309.3	1343.2
Specific consumption, LCD	67	70	73	76	79	82	85	88
Resid. & Comm. demand, m^3/d	40,435	48,588	58,266	69,487	82,802	97,241	111,289	118,204
Distribution Losses	28.0%	27.2%	26.3%	25.4%	24.6%	23.8%	22.9%	22.0%
Required Resid. Supply, m^3/d	56,169	66,741	79,004	93,146	109,817	127,612	144,344	151,544
Required Indust. Supply, m^3/d	0	0	0	0	0	0	0	0
Other Requirements, m^3/d	14,873	18,082	21,785	25,982	29,253	33,943	39,312	45,545
Total Demand, m^3/d	71,032	84,823	100,789	119,128	139,070	161,555	183,656	197.089
Available Resources, m^3/d	98,126	91,646	105,902	105.902	105.902	105.902	105.902	105.902
Deficit, m^3/d	-27.094	-6,822	-5,113	13,226	33,168	55,654	77,755	91,188

TABLE 58: ESTIMATION OF WATER DEFICIT IN MOSTAGANEM / ORAN (LA MACTA)

Year	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	1140	1280	1420	1556	1687	1815	1937	2062
Specific consumption, LCD	150	160	170	180	190	190	200	200
Resid. & Comm. demand, m^3/d	171,000	204,800	241,300	280,080	322,430	344,850	387,400	412,400
Distribution Losses	35%	33%	30%	25%	25%	25%	20%	20%
Required Resid Supply, m^3/d	263,077	305,671	344,714	373,440	429,907	459,800	484,250	515,500
Required Indust. Supply, m^3/d	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000
Other Requirements, m^3/d	0	0	0	0	0	0	0	0
Total Demand, m^3/d	340,077	382,671	421,857	450,440	506,907	536,800	561,250	592,500
Available Resources, m^3/d	307,000	307,000	416,000	501,000	501,000	232,000	68,000	68,000
Deficit, m^3/d	33,077	75,671	5,857	- 50,560	5,907	304,800	493,250	524,500

TABLE 59: ESTIMATION OF WATER DEFICIT IN SALLUM / TOBRUK

Year	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	237	282	334	395	464	539	620	702
Specific consumption, LCD	114	129	144	167	183	200	217	234
Resid. & Comm. demand, m^3/d	27,059	36,422	47,934	65,885	84,814	107,836	134,826	164,138
Distribution Losses	26%	26%	26%	22%	22%	20%	20%	20%
Required Resid. Supply, m^3/d	36,578	49,463	65,178	84,031	108,292	134,845	168,533	205,147
Required Indust. Supply, m^3/d	5,238	12,035	19,339	12,574	16,715	22,552	29,873	40,079
Other Requirements, m^3/d	4,600	7,300	10,400	13,300	17,500	20,900	26,100	32,000
Total Demand, m^3/d	46,416	68,798	94,917	119,905	152,507	187,197	234,506	277,226
Available Resources, m^3/d	36,500	38,000	37,500	37,000	36,500	36,000	35,500	35,500
Deficit, m^3/d	9,916	30,798	57,417	82,905	116,007	152,297	199,006	242,226

TABLE 60: ESTIMATION OF WATER DEFICIT IN ZWARA / ZARZIS

Year	1990	1995	2000	2005	2010	2015	2020	2025
Population, thousands	835	977	1137	1320	1527	1737	1936	2030
Specific consumption, LCD	98	104	109	120	127	135	143	153
Resid. & Comm. demand, m^3/d	82,272	101,558	124,546	158.699	193,897	234,069	276,679	310,677
Distribution Losses	26%	26%	25.6%	22.5%	22%	21.6%	21.2%	20.8%
Required Resid. Supply, m^3/d	111,947	137,368	167,436	204,661	248,686	298.647	351,093	392.123
Required Indust. Supply, m^3/d	10,119	13,655	18,039	24.880	32,287	43,563	57,704	77,418
Other Requirements, m^3/d	14,873	18,082	21,785	25.982	29,253	33.943	39,312	45.545
Total Demand, m^3/d	136.933	169,105	207,254	255.523	310,226	376.153	448.109	515,086
Available Resources, m^3/d	158,126	151,646	165,902	165.902	165,902	165,902	165,902	165,902
Deficit, m3/d	-27,094	33,268	67,287	110.177	164,810	227,606	297,074	349.184

TABLE 61: SUMMARY OF WATER DEFICIT IN THE REFERENCE SITES (1000 m^3/d)

Site / Year	1990	1995	2000	2005	2010	2015	2020	2025
1. Sallum	5.8	17.2	32.3	42.6	57.4	71.1	92.1	107.6
2. Tobruk	4.4	13.6	25.1	40.3	58.6	81.1	106.9	134.6
3. Sallum/Tobruk	9.9	30.8	57.4	82.9	116.0	152.2	199.0	242.2
4. Benghazi	11.2	60.1	119.6	198.0	292.5	408.6	541.9	685.0
5. Sirt	2.3	13.5	27.1	45.0	66.5	93.2	123.7	156.4
6. Tripoli	19.5	119.5	240.9	400.9	593.8	830.6	1102.8	1395.0
7. Zwara	5.9	24.3	46.5	76.4	111.2	154.6	204.4	258.0
8. Zarzis	-27.1	-6.8	-5.1	13.2	33.2	55.7	77.8	91.2
9. Zwara/Zarzis	-21.2	17.5	41.4	89.6	144.3	210.3	282.2	349.2
10. Mostaganem	1.2	7.5	13.5	-11.2	0	74.8	80.3	86.5
11. Oran	31.8	68.1	-7.6	-39.3	5.9	230.0	413.0	438.0
12. Mostagenem/ Oran	33.0	75.7	5.9	-50.5	5.9	304.8	493.3	524.5
13. Laayoune	1.1	-2.6	-0.4	1.9	4.6	7.2	10.2	14.9

5.2.6 Composite Sites

Three of the above sites were identified as possible locations for larger desalination plants to serve the needs of two nearby sites. These are:

1. Oran in Algeria to serve Oran and Mostaganem.
2. Sallum in Egypt to serve Sallum (Egypt) and Tobruk (Libya).
3. Zarzis in Tunisia to serve South Tunisia and Zwara (Libya).

Because of the proximity of each of the above locations, there might be certain advantages in installing one desalination plant to serve the needs of the two areas, such as benefiting from the economy of scale for the desalination plant, storage facilities, and pumping stations.

The sites of Sallum/Tobruk and Zwara/Zarzis could also serve an important goal which is improving regional co-operation in the peaceful uses of atomic energy. Such thinking has been promoted and encouraged by the recent moves in Egypt, Libya and Tunisia towards more integration and joint development of border areas.

The deficit to be filled by the proposed joint desalination plants for the above sites was obtained by combining Tables 40 and 43, Tables 47 and 52, and Tables 54 and 56. The results are shown in Tables 58, 59 and 60 respectively.

Table 61 summarizes the development of water deficit in all sites considered in this chapter from the year 1990 to the year 2025.

5.3 REFERENCE SITES

The eleven sites presented in the previous section were reduced to a more manageable number of cases based on 1991 data by the following rationale:

- One reference site was selected from each of the five NACs, yielding five sites.
- Within the Region, the sites were selected to give a representative distribution of water plant capacities ranging from relatively small (24,000 m^3/d) to very large (720,000 m^3/d). Hence, a reasonable interpolation of water cost can be made for any of the sites discussed in Section 5.2 from the results of the cost calculations.

The locations and capacities of the five reference sites for the cost calculations are marked in Figure 3. For the reasons stated earlier, the capacities required for these sites in the year 2005 are based on 1991 projections.

Should the NACs wish to endorse one reference site for further investigations, the site of Oran might be a good candidate for the following reasons:

- It is located in an area which will have no water resources from the year 2010, and will serve the needs of two large population centers, namely Oran and Mostaganem.
- It has already been qualified as a nuclear site through a study carried out by Sofratom and AECL in the period 1976-1984.
- A preliminary water connection study was carried out.

6. DESALINATION PROCESSES

6.1 GENERAL

General descriptions of the technically available and theoretically possible seawater desalination processes are given in numerous publications. Therefore, a detailed description of desalination processes in this study is not required. Only main processes and general comparisons are discussed. Only Multi-Stage Flash Distillation (MSF), Multiple Effect Distillation (MED), and Reverse Osmosis (RO) have been investigated within this study, as no other seawater desalination process has been industrially used in large scale and no other process seems likely to become industrially available within the next two decades. This fact does not rule out the need for Research and Development (R&D) in new desalination processes, on the contrary it points out the strong need for a new R&D activity in seawater desalination.

Table 62 shows a comparison between the main thermal seawater desalination processes, namely MSF with Brine Recycle (MSF/BR), MSF-Once-Through (MSF/OT) and MED. Table 63 shows a comparison for distillation and RO desalination systems.

In order to be able to concentrate only on the most promising desalination systems, a pre-evaluation utilizing the same methodology as in a recent IAEA study [27] has been applied to MSF/OT, MED and RO. The results are shown in Figures 13 and 14. The results indicated in Figure 13 show that the specific water costs for MSF plants in combination with "Single Purpose Nuclear Heating Plants" are about 45 - 55% higher than the specific water costs from MED plants. The result in Figure 14 shows that the specific water costs for dual purpose plants for RO and MED-plants are in the same range. Again the specific water costs from MSF plants are about 45 to 55% higher. Therefore, only MED plants and RO plants have been selected for the North African Study, as in all cases MSF plants are resulted in unattractive specific water costs.

6.2 THERMAL DESALINATION PROCESSES

6.2.1 Multi-Stage Flash Distillation (MSF)

There are two main reasons for higher specific water costs in MSF plants than MED. The first reason is the relatively low heat transfer coefficients in MSF plants compared with MED. The non-equilibrium losses are also higher in MSF plants. Therefore, the heat transfer area at the same overall temperature difference is considerably higher for MSF plants than for MED. This results in higher investment costs for MSF.

The second reason is that the overall temperature difference to reach a certain Gain Output Ratio (GOR) is lower in MED plants than in MSF plants. This results in higher energy costs due to the higher power loss in MSF plants. The lowest specific energy consumption which can be reached in MSF plants is about 55 $kWh(t)/m^3$ and 3.5 $kWh(e)/m^3$. The main advantage of MSF is the simplicity of the process and its proven reliability. At very low energy costs and with a very low cost of manufacturing and materials, MSF might possibly be the process of choice. However, with present high costs of energy, material and manufacturing, it is very difficult to justify, from the economic point of view, MSF plants except in special cases for smaller plants.

6.2.2 Multiple Effect Distillation (MED)

There are two basic types of MED plants namely the VTE (Vertical Tube Evaporation) and the HTME (Horizontal Tube Multiple Evaporation). The main difference between HTME and VTE is that, in VTE plants the feed (seawater/brine) is inside the vertically arranged heat transfer tubes and the condensation of the heating steam occurs outside the heat transfer tubes. In HTME plants

TABLE 62: COMPARISON OF THERMAL SEAWATER DESALINATION PROCESSES MSF/BR - MSF/OT - MED

	MSF-BR (Brine-Recycle)	MSF-OT (Once-Through)	MED (thin film arrangements)
Principle of steam	flashing	flashing	boiling/evaporating
Max. practical GOR (GOR=Gain Output Ratio)	10	12	25
Total ΔT per effect or stage	highest 4.5 ^{0}C at cold end 2.5 ^{0}C at hot end	medium 4.0 ^{0}C at cold end 2.0 ^{0}C at hot end	lowest 2.2 ^{0}C at cold end 3.5 ^{0}C at hot end
Number of effects or stages to reach a given GOR	GOR = 5: 12-16 GOR = 8: 18-28 GOR = 10: 30-35	GOR = 5: 12-18 GOR = 8: 28-32 GOR = 10: 35-42 GOR = 12: 39-45	GOR = 5: 6 effect GOR = 10: 10 effect GOR = 15: 19 effect GOR = 20: 27 effect GOR = 25: 40 effect
Temperature limits due to scaling using threshold effect	121 ^{0}C	135 ^{0}C	135 ^{0}C
Boiling point elevation loss	highest, due to higher concentration of feed (brine)	lower, due to simple concentration of feed (seawater)	lower, due to simple concentration of feed (seawater)
Non-equilibrium losses	high	high	low, mainly due to thin film
Heat transfer coefficient	plain tubes average: 3.0 - 3.5 kW/m^2 ^{0}C (Tmax: 90 - 120 ^{0}C)	plain tubes average: 2.7 - 3.7 kW/m^2 ^{0}C (Tmax: 110 - 130 ^{0}C)	thin film average: 4 kW/m^2 ^{0}C (Tmax: 70^{0}C) 5 kW/m^2 ^{0}C (Tmax: 110 - 130 ^{0}C)
Heat transfer area required at same overall T effective	highest, due to low heat transfer coefficient and highest boiling point elevation	high	lowest, due to lowest boiling point elevation and highest heat transfer coefficient
Combination with heat pump (vapor compression)	not economic	not practical	very economic for certain cases
Seawater/brine in evaporator	highest (7-12 times product flow)	high (6-10 times product flow)	lowest (2-3 times product flow)
Total seawater requirement	Same at same GOR	Same at same GOR	Same at same GOR

TABLE 62: COMPARISON OF THERMAL SEAWATER DESALINATION PROCESSES MSF/BR - MSF/OT - MED
(CONTINUE)

	MSF-BR (Brine_Recycle)	MSF-OT (Once-Through)	MED (thin film arrangements)
Antiscaling additive consumption	0.01 kg/m^3 product (T_{max} 90 ^0C) 0.02 kg/m^3 product (T_{max} 100 ^0C	0.022 kg/m^3 product (T_{max} 115 ^0C) 0.03 kg/m^3 product (T_{max} 130 ^0C)	0.022 kg/m^3 product (T_{max} 115 ^0C) 0.03 kg/m^3 product (T_{max} 130 ^0C)
Pumping power requirements	highest (4 $kWhe/m^3$ product) excluding product treatm. and transfer	high (3.5 $kWhe/m^3$ product) excluding product treatm. and transfer	low (1.5 $kWhe/m^3$ product) excluding product treatm. and transfer
Total volume of evaporator	highest	slight small than MSF-BR at same T	slight small than MSF-OT at same T
Cost for piping and valves	highest	high	lowest
Load changes	50 - 100 %	50 - 100 % easy in all case	40 - 100 %
Resistance against fouling (on line cleaning with rubber sponge cleaning system)	high (possible)	lower than MSF-BR (possible)	same as MSF-BR (not possible)
Cost of plant at same GOR, same T and same construction materials	highest	about 15 % less than MSF-BR	about 15 % less than MSF-OT
Maintenance cost	highest	lower than MSF-BR same as MED	lower than MSF-BR same as MSF-OT
Reliability	high	higher than MSF-BR	GOR > 12 as MSF-OT GOR < 12 highest
Corrosion risk	Same for all process at same top temperature	Same for all process at same top temperature	very low at GOR < 12, due to low top temperature
Potential for further improvements	very low	low	medium
Largest sizes in operation or under construction	60,000 m^3/day	12,000 m^3/day	17,000 m^3/day
Demonstration schemes built for	60,000 m^3/day	12,000 m^3/day	57,000 m^3/day
Largest practical unit	60.000 m^3/day	72.000 m^3/day	60,000 m^3/day

TABLE 63: SUMMARY OF SELECTED DESALINATION PROCESSES

		RO	MSF	MED	MED/VC
Energy consumption elec. thermal	 (KWe h/M³) (KWt h/M³)	 5 - 7 none	 4 - 6 55 - 120	 2 - 2.5 30 - 120	 7 - 9 none
Electric equivalent for thermal energy	(KWe h/M³)	none	8 - 18	2.5 - 10	none
Total equivalent energy consumption	(KWe h/M³)	5 - 7	12 - 24	4.5 - 12.5	7 - 9
Possible unit size	(M³/d)	24,000	60,000	60,000	24,000
Limiting factors		pumps vacuum units	pumps valves	erection and construction aspects: plant reliability	compressors
Total capital costs		lowest	highest (at same GOR)	low	medium
Fully automatic and unattended operation		possible	possible	possible	possible
Tolerance to operator faults		low	medium	high	medium
Tolerance to change sea water composition and pollution		medium	medium	high	high maintenance
Maintenance requirements		high	medium	low	medium
Spare parts or replacement parts requirements		high (delicate, large pumps, expensive membrane replacement every 3 - 5 years)	medium (large special pumps)	low (only small pumps required)	high (vapour compressor required)
Heat transfer area		not applicable	high	low	low
Failure potential if corrosion occurs		high (some membrane are sensitive to dissolved metals)	medium	low	low
Scaling potential when solutes in seawater are above precipitation level		high	medium	low	low
On-site assembly/erection requirements		low	medium	medium	medium
Engineering requirements (quantitative)		low	medium	medium	high
Manufacturing requirements		high (especially for membranes)	medium	low	medium
Ratio between product and total seawater flow		0.3 - 0.5	0.08 - 0.15	0.1 - 0.25	0.4 - 0.6
Experience available		medium	highest	high	medium
Potential for further improvement		high	low (at technological limit)	medium	medium

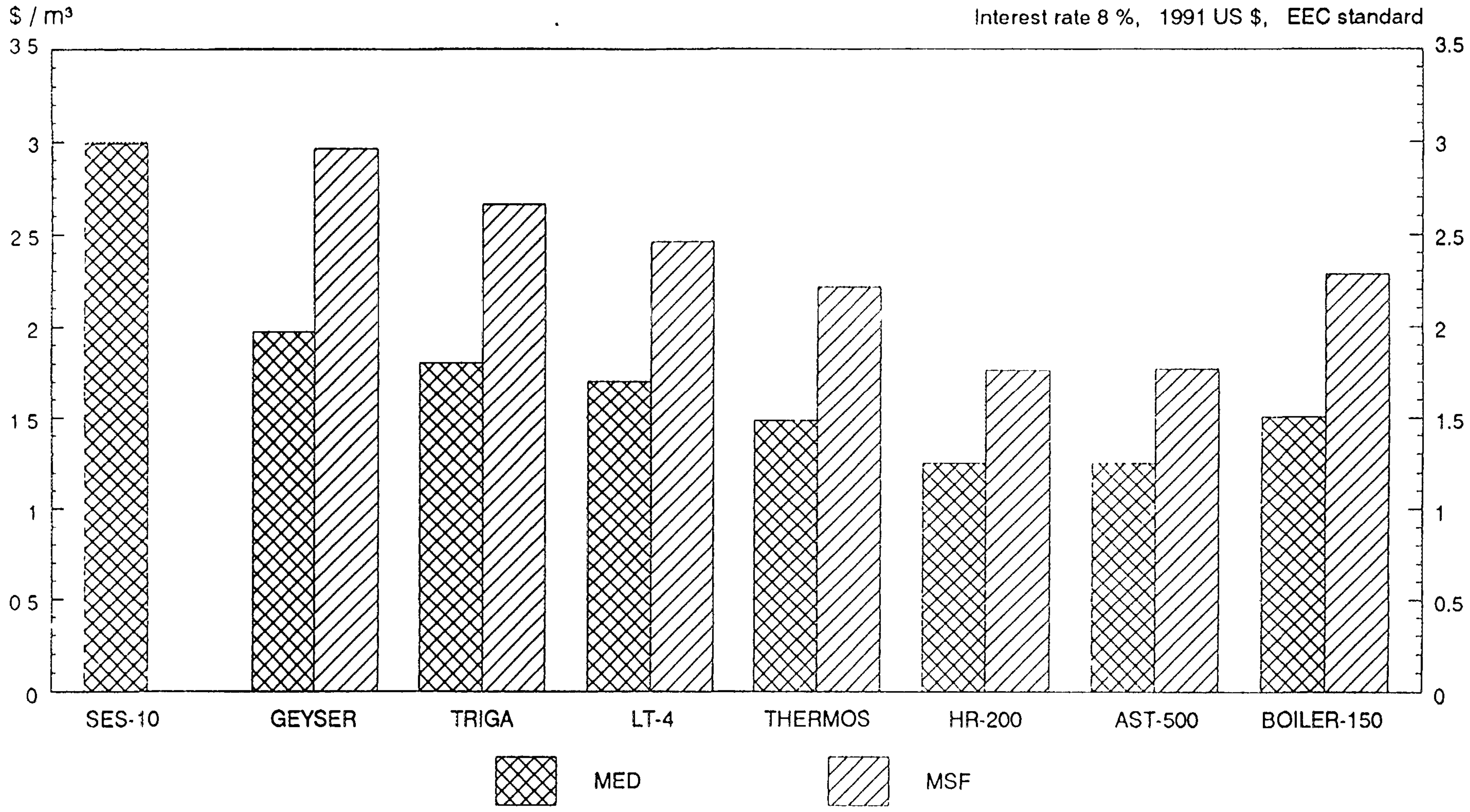


Fig. 13: *Water costs of destilation plants (Single purpose heating plants)*

(Data given in this figure are only indicative)

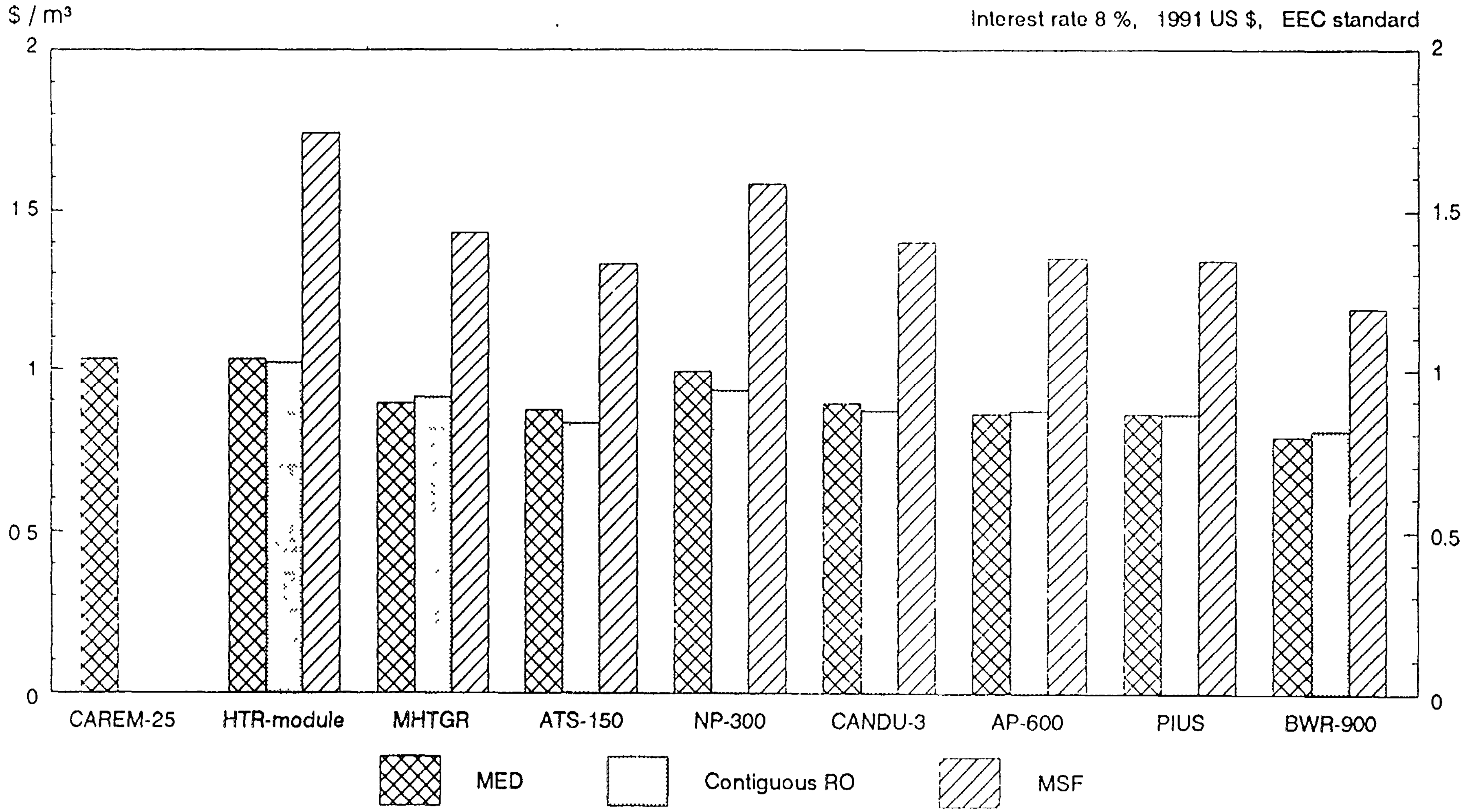


Fig. 14: *Water costs of destilation plants*
(Electricity production / Dual purpose plants)

(Data given in this figure are only indicative)

the feed (seawater/brine) is outside the horizontally arranged heat transfertubes and the condensation of the heating steam takes place inside the heat transfer tubes.

The effect of the different arrangements and flows in MED plants is higher heat transfer coefficients than that of MSF (plain tube) plants. HTME has better heat transfer coefficients in the temperature range of 20 ^{0}C to 70 ^{0}C, while VTE plants have better values in the range above 70 ^{0}C. Therefore, for low temperature plants it seems preferable to select HTME, and for high temperatures plants combined with a heat pump, VTE is a better choice. For large plants (>30,000 m^3/d) it might be economic to select a combination of HTME and VTE. Another advantage of MED, compared with MSF, is that there are less special components (i.e. no expensive brine recycle pump, no large diameter control valves in the brine and blowdown system). Therefore, the share of local participation could be higher for MED. It seems possible to realize, without any special effort, approximately 75% of the total investment cost locally for large scale MED plants (>24,000 m^3/d) in most of the NACs.

Low temperature HTME enables the use of low cost materials such as aluminum for the heat transfer surfaces and tube-sheets, and carbon steel for the vessels. This provides optimal lower temperature differences (driving forces for heat transfer) which in turn reduces the cost of energy. MED is also less sensitive to corrosion, scaling and fouling than MSF. The reliability is therefore higher and the damages are less if these phenomena occur.

Within this study for the plants with a GOR $\leq$ 12 (T $\leq$ 72 ^{0}C) HTME has been selected. For plants with a higher GOR (higher top brine temperature, maximum 135 ^{0}C) the investment cost of HTME and VTE are in a similar range. Therefore no specific differentiation is required. The unit sizes of the MED plants which have been evaluated in this study are 2,000 m^3/d, 6,000 m^3/d, 12,000 m^3/d, 24,000 m^3/d and 48,000 m^3/d. Actually there is no MED plant with capacities of 24,000 m^3/d and 48,000 m^3/d in operation. However, the scale up from 12,000 m^3/d or 17,000 m^3/d, unit sizes in operation on a commercial basis, by a factor of about 2 to 3 is relatively safe. Additionally, various modular demonstration programmes (e.g. the OSW-VTE module in Fountain Valley, California, USA) have clearly shown that even larger unit sizes can be built safely. The lowest specific energy consumption which has been demonstrated for MED plants is about 25 kWh(t)/m^3 at 130 ^{0}C and about 1.5 kWh(e)/m^3. The GORs and the top temperatures for the various cases have been selected independently of the amount of water required and the energy source.

6.3 REVERSE OSMOSIS (RO)

During the last decade RO plants have been demonstrated to be reliable, large scale industrial installations, provided that all systems of the plant, especially the pretreatment, are well engineered and well maintained. A careful examination of the cases where RO systems have failed shows that plant designers, due to lack of experience or understanding of the basic requirements, often made minor mistakes resulting in high costs for overhaul.

There are four major different membrane/module systems on the market (spiralwound cellulose acetate, capillary cellulose acetate, spiralwound polyamid thin film, and hollow fine fiber polyamid) manufactured by several suppliers. Other membrane/module systems (plate and frame, tubular) are of minor importance for large scale seawater desalination. Due to the different physic-chemical structure of the above mentioned membrane modules, their behaviour and resistance against certain water components are different. For example, certain membranes are very sensitive to chlorine, others have a very limited stability outside the PH-range of 3 - 6, or are affected by free oxygen, etc. Therefore, each membrane needs a specific pretreatment.

Optimizing the membrane/module system and pretreatment will result in an industrially reliable plant, and certain combinations can result in an additive free operation. A small demo-plant

(360 m^3/d) is in operation since April 1994 in Libya, working up to a recovery ratio of 50% using Mediterranean seawater without additives. The energy consumption for this plant is only 4.0 kWh(e)/m^3. Larger RO plants are now reaching an energy consumption of about 4.5 - 5.0 kWh(e)/m^3. Larger plants have a higher energy consumption than smaller ones. This is due to the fact that in small plants piston pumps with a high efficiency (92%) can be used whilst larger plants need centrifugal pumps with a maximum efficiency of about 88%.

Despite the fact that RO is a modular system in principle, and hence permits any required size, a certain adaptation is required to ensure the availability of components such as pumps, valves and filters and to the maximum transport dimensions. The largest pumps which are currently readily available are in the range of 2,200 - 2,500 m^3/h and 80 bar. This limits the size of an industrial unit to about 24,000 m^3/d. Therefore, this unit size was used for most of the cases considered in the present study.

One of the disadvantages of RO is the continuous deterioration of the membranes' performance, resulting in a limited life time for the membranes. Most of the manufacturers give guarantees for the membranes up to five years. Although there are several examples with large plants where the lifetime of the membranes was only one year or even less, there are on the other side a number of plants that have demonstrated a life time longer than 5 years. Therefore, 5 years has been selected as a basis for calculating the cost for membrane replacement in the study.

7. ENERGY SOURCES

7.1 GENERAL

Desalination processes require energy in the form of heat and/or electricity which could be supplied by nuclear power. The competitiveness of nuclear power with alternative power generation is an important factor in nuclear power development. Energy cost was found to be 35% to 58% of the total desalted water cost. Therefore, the correct source of primary energy for seawater desalination must be selected. Hence, scanning of a wide range of energy sources is essential. However, because the focus in this report is on nuclear energy, investigation of other energy sources is confined to providing a gauge to the economic competitiveness of nuclear energy.

It should be born in mind that the most reactors built worldwide have been either larger power reactors, or small research reactors. Cogeneration using the large reactors could pose a significant distribution problem in some areas, whilst a major engineering investment may be required to convert the research reactors into economic sources of heat for desalination purposes.

The energy source could be a DEDICATED or NON-DEDICATED plant. The former provides energy exclusively for the desalination process and in this case water is the only product out of the compound. The latter, which is much larger in size, provides only part of its energy to the desalination process. The rest of the generated energy (usually in the form of electricity) is sold to other customers. In both cases the energy source could be either a single purpose plant (i.e. generates only one form of energy, e.g. electricity or heat) or a dual purpose plant supplying both electricity and heat to the desalination process.

Desalination facilities are in operation in the Middle East, North Africa and Caribbean in combination with fossil power plants, and in Kazakhstan with a 300 MW(e) Nuclear Power Plant (NPP) at Aktau. These installations for co-production of electricity and water have some advantages over producing water alone through dedicated plants. These are [24] :

- Better load factor because, during an outage of the desalination plant, the energy source can still generate electricity for the grid. If RO is used, water production can be maintained during an outage of the energy source, utilizing electricity from the grid.
- Operational flexibility because more electricity can be produced during periods of low water consumption.
- Lower specific cost (US $\$/m^3$) due to economy of scale.

Small dedicated nuclear plants may be attractive to the North African Countries due to their advantages over much larger non-dedicated plants, there are [24, 28]:

- Lower absolute capital cost.
- Potential reduction in construction time.
- Simpler organizational requirements.
- Reduced complexity in allocating costs.
- Smaller size of components increases the potential for domestic participation.
- Earlier introduction of nuclear energy with potential for technology transfer.
- Easier financial arrangements.

This Chapter presents a short introduction and technical summaries of various nuclear reactors, fossil fired plants, and other energy sources. The aim is not to repeat the more detailed information that can be found in other sources. The aim is, rather, to highlight the important features and technical data that might have an impact on the economics of utilizing nuclear energy for seawater desalination.

7.2 NUCLEAR REACTORS

Most of the reactors considered in this study are advanced Small and Medium Power Reactors (SMPRs), of which some are expected to be commercially available by the year 2005, however, there are also many large reactors already commercially available. The main sources of information were IAEA, [28-31] and OECD [32] as well as data provided by vendors as a reply to IAEA's Questionnaire [33], and in their technical publications [34-49]. These reactors are in varying stages of development.

Table 64 lists technical data for the nuclear reactors, as well as other energy sources surveyed in the present study. All the reactor information contained in this Table is based exclusively on the answers to the IAEA's questionnaire; no attempt has been made to assess it in any way. More details on the technical characteristics of the reactors are provided in Reference [21]. These reactor designs are based on a variety of concepts: Pressurized Light Water-cooled Reactors (PWR), Pressurized Heavy Water-cooled Reactors (PHWR), High Temperature Gas cooled Reactors (HTGR), and Liquid Metal Cooled Reactors (LMCR). These designs, also, offer diverse applications: heat production only, simultaneous heat and electricity production, and electricity generation only.

Technical characteristics of Nuclear Heating Reactors (NHRs) and different types of Nuclear Power Reactors (NPRs) are briefly outlined below.

7.2.1 Nuclear Heating Reactors

Although NHRs are designed to satisfy different boundary conditions, obeying different safety regulations and criteria and following different technological lines, they all present some common characteristics [30, 32] :

- Due to lower coolant temperature, in the primary circuit, for supply of heat compared to electricity generation, NHRs are of lower capacity output, with lower core power densities, and with working pressures about ten times smaller than that of a typical PWR.
- The design of these reactors is integrated and makes as much use as possible of components and systems proven in the operation of larger NPPs.
- Most of the NHR concepts considered make extensive use of passive systems and components and rely more heavily on natural processes rather than engineered safeguards.
- The operating schemes proposed for all NHRs are considerably simplified, including for some of them, totally unmanned operation.

7.2.2 Nuclear Power Reactors

7.2.2.1 Water Cooled Reactors (WCR)

Most of the reactors in Table 64 are water cooled reactors. These include light water cooled reactors (LWR), of both the pressurized (PWR) and pool type, and pressurized heavy water cooled reactors (PHWR). The two essential distinguishing characteristics of these two reactor types are:

- in a PWR, the use of light water (H_2O) as moderator and coolant, and the use of enriched uranium as fuel, and
- in a PHWR, the use of heavy water (D_2O) as moderator and coolant, and the use of natural uranium as fuel.

The trends in advanced PWR and PHWR design and technology have been directed towards innovative designs and concepts, enhanced safety, evolutionary improvements in plants, improved

TABLE 64: TECHNICAL DATA OF ENERGY SOURCES

Reactor	Country	Type	Size MWe/MWt	Fuel	Maximum steam temperature ^0C	Primary temperature ^0C	Primary Pressure (MPa)
AST-500	CIS	PWR Integrated Vessel	500 MW_t	UO_2 (2.0%)	160	141/205	2.0
GEYSER	Switzerland	PWR Pool	23 MW_t	UZrH (19.7%)	148	155/166	0.72
HR-200	China	PWR Integrated Vessel	200 MW_t	UO_2 (<3.0%)	140	135/200	2.2
LT-4	CIS	PWR Vessel	80 MW_t	UO_2 (<10.0%)	300	278/372	12.8
SES-10	Canada	PWR Integrated Pool	10 MW_t	UO_2 (<2.5%)	95	73/95	0 35
THERMOS	France	PWR Integrated Pool	100 or 150 MW_t	UO_2 (<3.5%)	137	133/144	1.0 - 1.1
TRIGA	USA	PWR	32 or 64 MW_t	UZrH			
AP 600	USA	PWR Vessel	1933 MW_t 600 MW_e	UO_2 (<3.6%)	271	280/316	15.5
CANDU 3	Canada	PHWR Pressure tubes	1439 MW_t 450 MW_e	Natural UO_2	260	260/310	9.9
CANDU 6	Canada	PHWR Pressure tubes	2158 MW_t 660 MW_e	Natural UO_2	260	260/310	10.0
CAREM-25	Argentina	PWR Modular Integrated Vessel	100 MW_t 25 MW_e	UO_2 (<3.9%)	286	278/326	12.25
NP-300	France	PWR Vessel	950 M W_t 300 MW_e	UO_2 (<4.0%)	293	278/312	15.5
GT-MHR	USA	HTGR	600 MW_t 287 MW_e	UCD	N/A	850/500	7.1
4S	Japan	LMCR Fast reactor Pool	125 MW_t 48 MW_e	U, Pu met (20 %)	455	355/510	0.1
Fossil Generator	General	Superheat / Reheat	600 MW_e	Gas/Oil	550	N/A	N/A
Fossil boiler	General	Saturated	36 - 80 MW_t	Gas/Oil	215	N/A	N/A
Gas turbine	General	Large Industrial	175 MW_e	Gas	N/A	N/A	N/A
Combined cycle	General	Large Industrial	450 MW_e	Gas	N/A	N/A	N/A
Diesel	General	Large Industrial	20 MW_e	Gas/Oil	N/A	N/A	N/A
Solar Pond	General	Small Industrial	50 MW_t	Insulation	N/A	N/A	N/A

fuel utilization, design simplification, and simplified and shorter plant construction. Examples of these include [32]:

- Integrated design, i.e. elimination of external primary system recirculation loops and pumps.
- Reduction of large bore primary piping.
- Elimination of safety grade coolant make-up systems.
- Increased in-vessel heat storage capacity.
- Application of passive emergency cooling.
- Application of passive residual heat removal systems.
- Location of reactor's pressure vessel penetrations in the upper part of the vessel for PWRs.
- Incorporation of large pressurizers (internal or external) for PWR's.
- Minimization of the number of seismic structures, simplification of the building concept and use of seismic isolation.
- Elimination of emergency diesels.
- Modularization of design to allow a higher degree of off-site manufacture and reduced construction time.

7.2.2.2 Gas Cooled Reactors (GCR)

Graphite moderated GCRs have been in operation for commercial power generation since 1956. The further development of the GCR in the USA, FRG, Switzerland and Japan has concentrated on the High Temperature Gas Cooled Reactors (HTGR), using helium as a coolant and a ceramic cladding of the fuel that is capable of retaining the fission products up to temperatures of more than 1600 ^{0}C. The so called "coated particle" is a common feature of all HTGRs, no matter whether the coated particles are embedded in a block-type or a spherical (pebble) graphite matrix. The specific safety features of HTGRs are mainly based on:

- The high temperature resistance of the all ceramic core structure.
- The large difference between operating temperatures and failure limits of the coated particles.
- Self-stabilization due to the combination of negative reactivity temperature coefficient and large margin for allowable temperature-rise.
- The low power density of the core (less than 75 kW/l).
- The large heat capacity of the graphite moderator and structures.
- The inert, phase-stable helium coolant.

Small power sizes and/or low operation temperatures such as required for district heating or desalination enhance the safety margins further so that even unstaffed operation seems to be possible for such a purpose.

7.2.2.3 Liquid Metal Cooled Reactors (LMCR)

In a fast neutron spectrum LMCR is possible to produce more fissile material than is being used for the fission process itself. Because moderating light materials have to be avoided in fast reactors cores, liquid metal (usually sodium) is used as a coolant. LMCR development work has been directed towards finding configurations that will produce electricity with cost competitive to LWR power cost. This could be achieved through making full use of simplification and modularization in small and medium reactors. In both cases the development aim is to enhance use of passive safety features mainly by the excellent heat capacity and natural convention capability of the sodium coolant for decay heat removal [32]. In addition to general LMCR design goals there are specific aspects for small LMCR:

- The enhancement and utilization of the inherent passive safety characteristics of LMCR systems which may be more easily achieved in smaller units.
- Increased utilization of the characteristics of liquid metal fast reactors to consume actinides and thereby reduce the toxicity level of spent fuel.
- Significantly reducing the plant's construction time by factory construction of small reactors.
- Significantly reducing the capital commitment.

The only demonstration plant in the world for seawater desalination using nuclear power was built in Aktau in Kazakhstan. The Aktau complex comprises a BN-350 LMCR, and a seawater Distillate Production Plant (DPP). The reactor design, its ability to self-control, and the reliability of the control, management, and protection systems all provide good nuclear safety characteristics. Prolonged operating experience of the BN-350 reactor with the desalination units demonstrated high efficiency and reliability, proving this to be a good solution to water supply problems for population and industry [24].

7.2.3 Provenness of Nuclear Technology

One of the factors that might impede the deployment of small reactors in the North African Countries is their First Of A Kind (FOAK) nature. Should nuclear desalination be implemented in the Region, it would be its first nuclear power reactor. Thus, these countries are unlikely to have the qualified manpower and other related infrastructure necessary to resolve major FOAK plant performance problems. Most likely they will require evidence of provenness. Provenness is a concept mainly intended to reduce commercial risk. There is no clear definition of when "provenness" is satisfactory. There is always a risk in any project, and what really matters to the decision maker is his assessment of the relationship between benefits expected and the risks incurred. A too rigid application of the provenness concept as a precondition would preclude taking advantage of the latest technological developments and improvements [21].

There are various degrees of provenness that could be assigned to a proposed nuclear plant, ranging from a very high degree of provenness if the proposed plant is nearly identical to one or more plants in successful commercial operation, to a very low degree of provenness if the nuclear plant design to a major degree encompasses novel or unproved concepts or components. The minimum requirements for provenness outlined in Reference [28] are cited below:

- The reactor and plant systems and concepts must have been demonstrated in an integrated manner in at least one power reactor at comparable ratings,

  or
- All key components, of the design and capacity proposed, must have significant operating experience in the offered size, under comparable operating conditions, in nuclear power plants or test facilities.

It is worth noting that, while a reference plant can be very helpful in demonstrating provenness, it is not the only solution to the provenness problem. In these cases the buyers appear to have put greater stress on the demonstrated experience of the supplier, rather than on the component and system provenness.

7.3 FOSSIL FIRED PLANTS

7.3.1 Fuel-Oil or Gas Plants

Gas turbines are the most flexible energy source for electric power supply up to 200 MW(e), because they can be built in a very short time and have low specific capital cost. Because of low efficiency (about 32%), fuel costs dominate in the electricity costs.

Fuel-oil or gas fired electrical plants are considered economic for units over 50 MW(e), with a well mastered technology, provided by many suppliers in the world The availability of the plants may be very high, however, the fuel resource base may be limited. In the same range, combined cycle gas and steam plants up to 600 MW(e) per system give a higher yield up to 50% efficiency The high technology level required for the construction and operation of these plants limits the number of plant suppliers But, the demand for such plants continues to be very high in view of their excellent performance

7.3.2 Coal Fired Plants

The heavy infrastructure needed for coal transportation and storage makes coal fired stations economic above only 200-300 MW(e) size, provided that average world coal prices remain at the present level, i e about 50 US$/ton CIF (Cost Insurance Freight paid) However inland transportation costs can be as high as 50% in addition to CIF prices

Coal stations are available from many suppliers The technology is well proven and with preventive maintenance, availability may be very high. The economic advantage of coal fired plants is tempered by strict pollution standards and by the necessary large investment for the required infrastructure, i e inland transport systems and storage facilities. Some improvements may be forecasted through fluidized bed combustion but, due to the above mentioned constraints, a decrease in present cost of coal fired stations is not expected

7.3.3 Diesel Plants

Diesel generators have made significant gains in energy efficiency and can be used from 100 kW(e) to as high as 50 MW(e). The maintenance requirements for modern low speed diesel engines are the lowest of all fossil energy systems

7.4 NEW AND RENEWABLE ENERGY SOURCES

7.4.1 Hydroelectricity

Electricity is produced by water turbines in dams, which often include also agricultural irrigation equipment However, water might not be available due to drought or insufficient precipitation. The power plants can be used as base load and peak load plants, from a few kW(e) to several thousands MW(e) The investment costs are very high, even when compared with nuclear, but the operating costs are low. Many plants have been built and proven to be competitive if electricity is used at a distance less than 1000 km for the biggest power plants and less than a few tens of km for the smaller ones Some potential sites for further development remain in Russia and developing countries.

7.4.2 Renewables

Other renewable energies such as solar and wind have limited potential with regard to seawater desalination. These technologies can produce some tens to hundreds of m^3/day or even more, but despite many years of development, they are still far from being economic. In specific situations, however, for smaller plants, solar ponds or thermal concentrators may become interesting For brackish water and many other decentralized inland applications, solar energy and especially photo voltaic may play an important role.

7.4.3 Waste Recovery

Incineration of waste is a suitable source for producing electricity or heat It allows the elimination of solid wastes and to utilize the energy produced Water, soil and landscape pollution are suppressed and air is kept clean through an efficient gas treatment system. Without energy recovery, incineration is a costly waste management process, but, when energy can be sold to a nearby user, it may become competitive. The energy recovery system accounts for about 20 to 25% of the incinerator construction cost. But the whole waste processing cycle should be evaluated and compared to other possible waste management options, in order to avoid any hidden subsidy.

8. COUPLING OF DESALINATION PLANTS WITH NUCLEAR REACTORS

8.1 GENERAL

In principle, the energy produced by thermal power units can drive desalination processes in two different ways:

- Mechanical, and/or electrical energy for processes that are based on mechanical work such as RO and MED/VC.
- Heat energy for distillation processes such as MSF and MED.

Also all desalination processes need mechanical work for pumping, and electricity for auxiliaries and services. Obviously, one nuclear unit can energize several processes via different forms of energy. Combinations of desalting processes may under some circumstances be attractive for improving the overall energy efficiency and reducing the water costs.

The reactor types listed in Chapter 7 represent advanced versions of the four available categories of reactors: Pressurized Light Water Reactors (PWR), Pressurized Heavy Water Reactors (PHWR), High Temperature Gas Cooled Reactor (HTGR) and Liquid Metal Cooled Reactors (LMCR). Coupling Nuclear Power Plants with desalination processes based on the type of energy needed, as well as examples of coupling different types of reactors with different desalination processes, are discussed below based on data available in the literature [21, 24].

8.2 COUPLING BASED ON ENERGY TYPE

8.2.1 Processes Requiring Mechanical Work

For the RO and MED/VC processes the energy source in general could be:

- Electricity supplied from a dedicated plant or the electrical grid;
  or
- Direct mechanical energy in the form of steam to drive the main compressors of MED/VC, and the high pressure pumps of RO processes, by steam turbines.

Electrical coupling of the NPP with an RO or MED/VC desalination plant is simple. All it requires is an electrical connection. This permits the most flexible arrangement in that siting, plant size, and timing can be considered independently. Concerning technical aspects, there are no mutual influences between the electricity generating plant and the RO desalination plant, except site specific, reliability and availability aspects. For example, water intake characteristics would have a substantial influence on site selection.

Joint siting of the NPP and the desalination plant, offers the advantage of the possibility of sharing water intake/outfall structures between the electricity generating plant and the desalination plant. If these structures are shared, the "contiguous plant" concept applies. If they are not shared, this corresponds to the "stand-alone plant" (see "Definitions"). There is no need for joint siting of the desalination plant and of the electricity generating plant. Transport of electricity is easy and cheap, even for relatively long distances. The siting of both plants can be readily optimized separately. As there is only an electrical connection with the desalination plant, there would be no risk of radioactive contamination reaching the potable water produced, and hence there would be no need for particular protection systems such as for example an additional intermediate heat transfer circuit.

In case of direct mechanical coupling, steam may be taken from an adjacent NPP that is either a dedicated plant for desalination only or dual purpose for electricity and water production.

This arrangement has potential advantages over electricity driven desalination plants due to eliminating AC generator and electric motor inefficiencies. On the other hand, many small turbines and steam lines are more expensive (per power unit) than electrical coupling and less efficient.

The exhaust steam from the turbine can be used to preheat feedwater for the desalination processes. In such arrangements, however, it would be necessary to eliminate the risk of radioactive contamination. A simple solution may be to maintain the seawater coolant in the condenser (the feedwater for the desalination process) at a pressure higher than that of the condensing steam, and to monitor the qualities of the condensate and coolant at their outlets from the condenser. This solution is acceptable only for PWR and PHWR, not for BWR, as the latter introduces primary coolant too close to the desalted water, which may not be sufficiently safe.

In view of the above mentioned drawbacks, and the risk of having radioactive traces in the condensate from PWRs and PHWRs, mechanical coupling with these types of reactors appears to be the least promising. Such mechanical coupling has less risk with HTGRs and LMCRs since the steam is at higher pressure than the primary cooling.

In addition to electrical coupling, it is also possible to provide a thermal coupling between the NPP and the desalination process. In this case, waste heat from the NPP, discharged as heated condenser cooling water, is used as preheat feedwater to the desalination process, thereby improving the efficiency of the process. This approach has an advantage over that of using steam from the adjacent NPP, in that the working fluid is one step further removed from the reactor. Hence the risk of radioactive carryover into the product water is reduced to a very low level. It also offers the benefit that it requires no expensive modifications to the NPP, and hence the advantages of using a standard reactor design can be realized. Because of its potentially significant economic benefits, this combined electrical/thermal coupling for desalination processes such as RO may be one of the more promising coupling schemes.

8.2.2 Processes Requiring Heat

For the MED or MSF processes, the energy to be supplied is mainly low temperature heat (hot water or steam). Electricity is also required for pumping water. The energy source can be:

- A single-purpose heat-only reactor (or a corresponding conventional fossil fueled boiler), and an additional electricity source;

  or
- A dual purpose nuclear (or fossil-fired) power plant.

In both cases, joint siting of the heat source and the desalination plant is necessary because transport over long distances of heat energy is expensive and implies unavoidable losses. Both plants must be adjacent, or at most separated by a short distance (few kilometers).

In order to maximize the economy of a project, energy waste should be avoided. Therefore, the steam from a water cooled reactor should be utilized so that the available energy in the condition at which it is supplied to the evaporation process is converted to mechanical energy. There are two typical pressures for process steam, which are of special interest:

Case 1 : 0.2 - 0.37 MPa (condensing temperatures 120 °C -140 °C) for MSF and MED (Multi-Effect Distillation). In these evaporation processes the maximum brine temperature should not exceed 121 °C to avoid scale problems. This, however, necessitates acid treatment for scale prevention with the inherent risk of corrosion. The use of modern high temperature additives permits satisfactory operation with brine temperatures of 108 °C - 110 °C. Most large modern MSF plants would today use the combination of sponge ball cleaning, with high temperature additives.

Case 2 : 30-40 kPa (Condensing temperatures 69 °C - 76 °C) for LT-HTME (Low Temperature Horizontal Tube Multi-Effect Distillation). Maximum temperatures should be in the range of 65 °C -72 °C.

Cases 1 and 2 above are determined by the desalination process. The steam cycle of the power unit has to be adjusted technically and economically to match these conditions to the extent possible.

8.2.2.1 Case 1: Highest Brine Temperature

The conditions of Case 1 are suitable for most of MSF and high temperature MED processes. However, the problem of matching the heat conditions of the heat source to the requirements of desalting processes is posed.

Almost 90% of the nuclear power plants now operating in the world are water cooled reactors (PWRs, BWRs and PHWRs). Almost all those which are now under construction also fall into this category. Therefore, the adequacy of the PWR and PHWR types to case 1 should be investigated. Compared to fossil power plants, and HTGRs and LMCRs, PWRs and PHWRs are characterized by the following features:

- Relatively low thermodynamic efficiency resulting from: (a) low steam temperature and pressure, and (b) wet steam, the expansion of which involves more energy losses. Thus more heat is released per kWh(e) produced.
- The pressure in the steam cycle is lower than that of the primary reactor coolant, thus leakage may carry radioactive traces to the power/water interface.

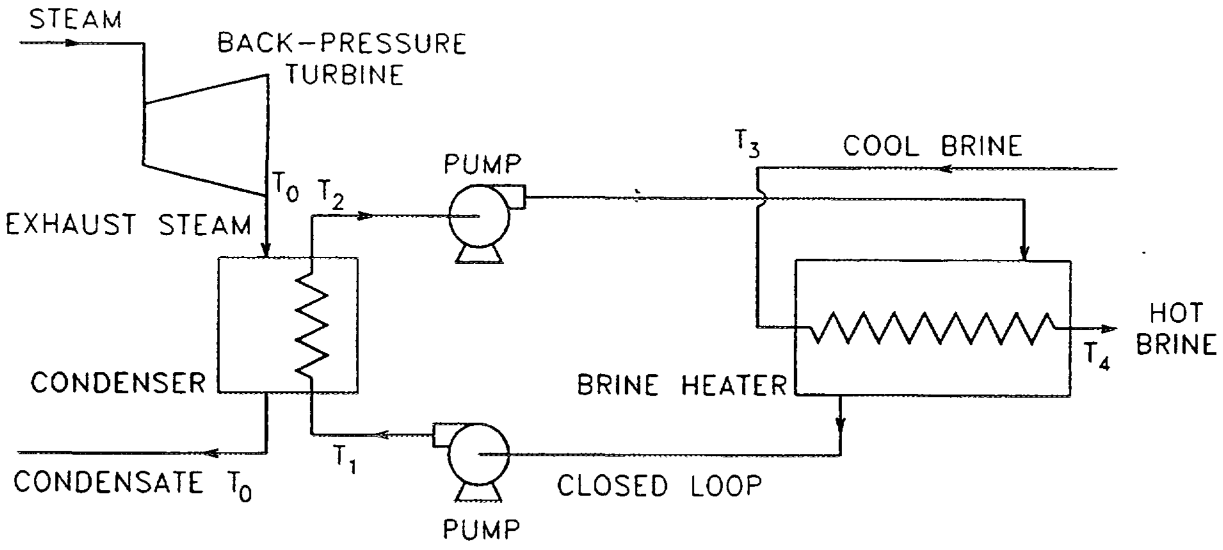
The BWR (Boiling Water Reactor) is less attractive for thermal desalination, as the primary reactor coolant - the motive steam - reaches the condenser, i.e. the heat source for the power/water interface. PWR and PHWR are safer as they have an additional barrier fluid between the reactor coolant and the desalination plant motive steam, i.e. the steam generator fluid. Therefore, they are preferable.

A different type of PWR and PHWR for desalination is the low pressure, small reactor that is designed for relatively low temperature (<130 °C) heat supply. This heat can be used for various low temperature industrial applications, district heating or desalination. A small amount of electricity can also be generated.

<u>Thermal Coupling for Case 1</u>

The thermal coupling consists of a heat transfer system between the steam or hot water from the nuclear unit and the saline water of the desalination unit. A stringent provision against radioactive contamination, which helps also against salination of the secondary coolant, is the "isolation loop" (Figure 15). This system consists of a closed loop placed between the nuclear steam and the water plant. In this system the exhaust steam is condensed and the heat is transferred to a medium within the loop which is then used to heat the brine. Two heat transfer media have been considered for use within the loop, namely pressurized water or boiling water. An analysis by ORNL [50] shows that if boiling water is used the loop does not seem to accomplish much. If pressurized water is used, the loop pressure can be kept at a higher pressure than the exhaust steam or the brine by operational control. If leaks develop in either the condenser or the brine heater the result would be leakage of water from the isolation loop into the steam or the desalination water plant. Since the quality of the loop water is controllable, neither of these contingencies would cause difficulty.

The pressurized water loop is, however, an expensive alternative. The capital and operating costs of isolating loops are obvious costs, including equipment, and energy for pumping of large amounts of water, as well as expensive heat transfer surfaces. Also, there is an additional cost



T_0 = Temperature of exhaust steam
T_1 = Low temperature in closed loop
T_2 = High temperature in closed loop
T_3 = Brine temperature prior to entering the brine heater
T_4 = Brine temperature at exit from the brine heater

Fig. 15: Pressurized water isolation loop

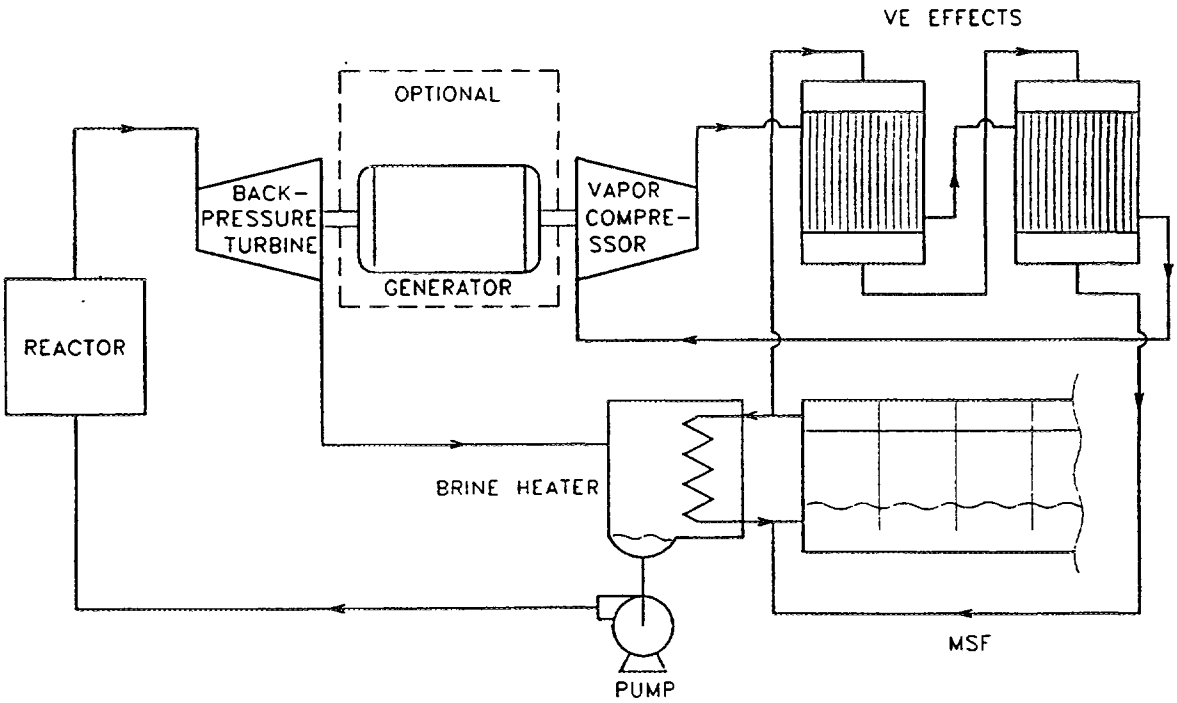


Fig. 16: MSF plant with vapor compresion - VE topping

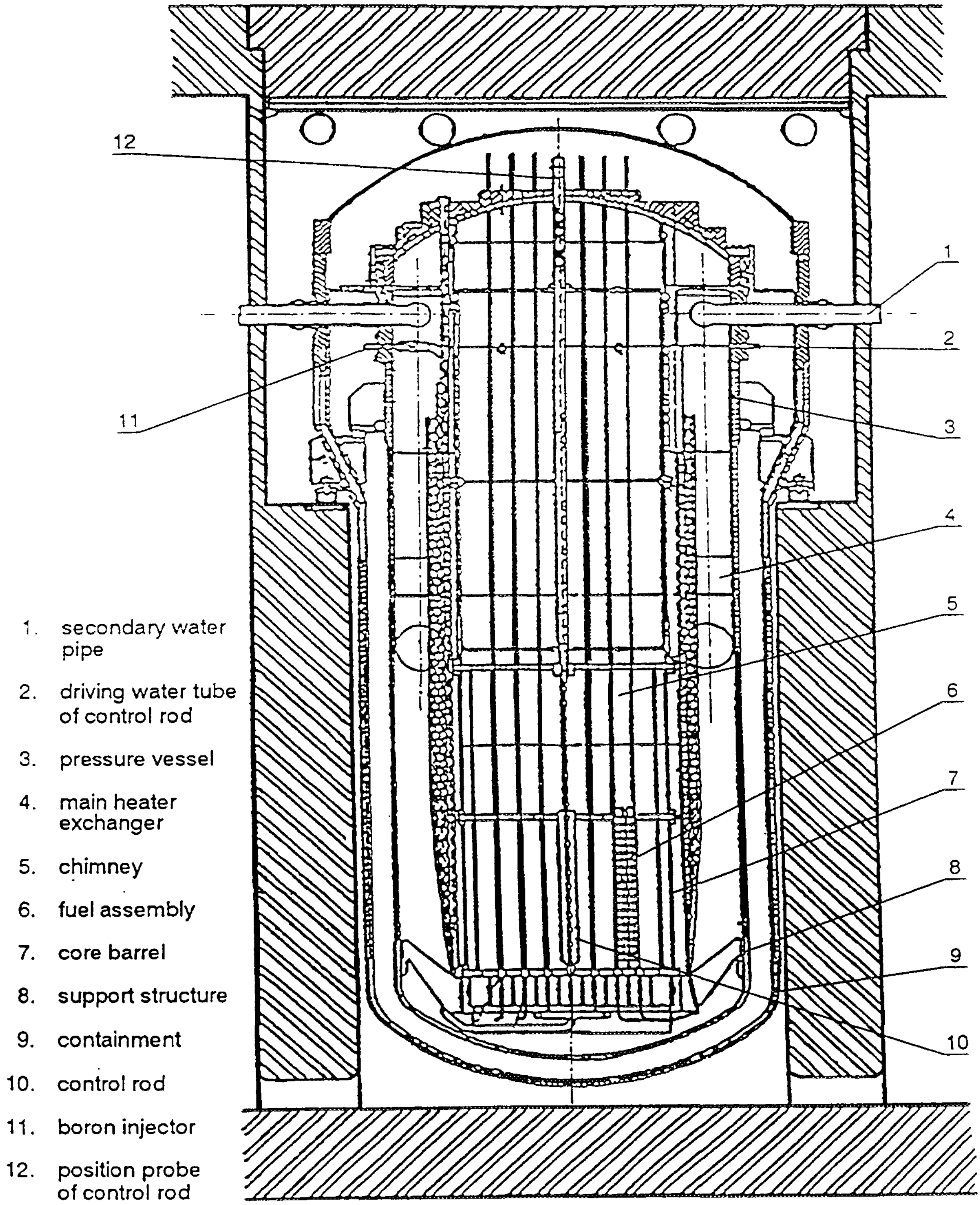


Fig. 17: Vertical section of the HR-200 reactor

attributable to the loop - the turbine must be operated at a higher exhaust pressure and temperature and/or the desalination process must operate at a lower temperature in order to supply the thermal potential necessary to cause the heat to flow through the loop. This results in a loss of electrical and /or water capacity. This loss of capacity constitutes an additional cost.

8.2.2.2 Case 2: Medium Brine Temperature

The conditions of Case 2 are suitable for making use of most low-cost evaporators. This case differs from case 1 in several essential aspects:

- Larger steam turbines of about 300 MW(e) are available that are capable of operating at the exhaust pressure of 30-40 kpa. Such turbines are designed to operate with dry cooling tower heat rejection.
- With MED the process operates at an optional temperature drop of 2.3 °C to 3 °C per effect, so that about 15 effects can be incorporated between the temperature of 72 °C and ambient temperature. The GOR obtained ranges between 10 to 12.2, that is about the same as in case 1, with a large saving in energy (the steam expansion between 0.2-0.3 MPa and 30-40 kpa is gained) and with some gain in pumping.
- The conditions in the brine heater, i.e., the thermal coupling, are much milder than in case 1. The temperatures are lower and the corrosion rates would be lower. The pressures, forces and stresses are smaller as well as the driving forces for leakage.

Thermal Coupling for Case 2

Thermal coupling considerations are qualitatively the same as in Case 1. Lower desalination system pressures make isolation more difficult. Although an isolation loop is a questionable solution for Case 1 due to a large economic impact, and even less viable for Case 2, it has some specific advantages for the latter, provided that the heat transfer medium is flashing saline water. This way, the cost of equipment, and energy of this loop is reduced, compared to a pressurized water isolation loop. On the other hand, the coupling with a pressurized desalted water loop is safer, simpler and more reliable than coupling with flashing saline water.

8.2.3 Hybrid Systems

Dedicated nuclear plants can be single purpose reactors, producing electricity or heat, or dual purpose reactors producing both electricity and heat. For the latter case it is advantageous to use the electricity generated to operate MVC or RO units in addition to the thermal processes. It is also possible to use the mechanical energy of the turbine to drive MVC unit as shown in Figure 16.

Where RO units are operated, another advantage comes from mixing the high purity desalted water from the distillation process with the less pure product of RO. The coupling schemes for hybrid systems with PWR or PHWR are the same as described in the previous sections.

8.3 EXAMPLES OF COUPLING NUCLEAR REACTORS WITH DESALINATION PLANTS

8.3.1 Coupling with PWR

In 1991 the Institute of Nuclear Energy Technology (INET) of the Tsinghua University, China, announced plans to construct a 200 MW(t) heating reactor (HR-200) to be operational by 1998. At the same time, the feasibility study of using the HR-200 for seawater desalination was carried out. Preliminary results showed that the heating reactor is suitable for desalination purposes. The main features of HR-200 (Figure 17) are :

- Integrated vessel.
- Natural circulation of primary coolant.
- Double pressure vessels.
- Hydraulic driving control rods.
- Natural circulation of heat removal system.

More technical data can be found in Chapter 7 and Reference [21]. To eliminate the possibility of radioactive leakage into the desalination system, INET adopted the concept of an isolation loop with pressure higher than that of the primary circuit. The arrangement is similar to that presented in case 1 above.

The desalination plant was originally chosen to be an MSF plant producing 77,000 m^3/d of desalted water, which corresponds to a specific energy consumption of 62.3 kWh(t)/m^3. Later, the desalination plant was changed to MED with two alternative operating modes. The first was as a heat only nuclear plant, producing 144,000 m^3/d of desalted water, and the second was Cogeneration, producing 120,000 m^3/d with a specific energy consumption of 50 kWh(t)/m^3. Figure 18 shows schematic arrangement of the HR-200/MED coupling without electricity generation. The same arrangement is also valid for the HR-200/MSF coupling.

8.3.2 Coupling with PHWR

In 1993 CANDESAL Inc., working closely with AECL (designer of the CANDU PHWR) and Seprotech Systems (a Canadian designer and manufacturer of RO water purification systems) initiated a design study to evaluate the extent to which performance enhancements and cost reductions could be achieved by taking advantage of an integrated systems approach to the design of a facility for the Cogeneration of water and electricity. The RO desalination process was selected for the water production plant because it is a relatively energy efficient process, it is a well proven technology, and yet it offers considerable promise for future improvement as membrane R&D continues. It also offered the very significant advantage of allowing an integrated system design incorporating both an electrical and a thermal coupling between the reactor and RO plant without requiring changes to any of the design or operating characteristics of the reactor. Hence a standard CANDU design configuration could be used. Key features of the CANDESAL design concept include:

- Use of condenser cooling water as the seawater feed stream to the desalination plant. This allows pre-heating of the feed stream by as much as 10 to 15^{0}C, resulting in improved RO system performance.
- Use of ultrafiltration (UF) as part of the RO feedwater pre-treatment. Using the UF filtrate provides a higher quality feedwater to the RO membranes, reducing the number of membranes required and improving their useful lifetime.
- Use of advanced design optimization techniques similar to those used in the nuclear industry to achieve UF and RO membrane configurations which yield optimum performance and cost characteristics.

A study was carried out for seawater conditions representative of the El-Dabaa site, for potable water production rates ranging from 240,000m^3/d upwards, and for both the CANDU 3 and CANDU 6 reactors [51]. The results of the study demonstrate that a properly integrated and optimized system design, taking advantage of both electrical and thermal coupling, can yield significant reductions in desalination plant capital cost and water production cost.

8.3.3 Coupling with HTGR

The Metropolitan Water District of Southern California (MWD), in conjunction with the US Department Of Energy (DOE), initiated a study [52] to evaluate the technical and economic viability of using the Modular High Temperature Gas Cooled Reactors (MHTGR) for desalination.

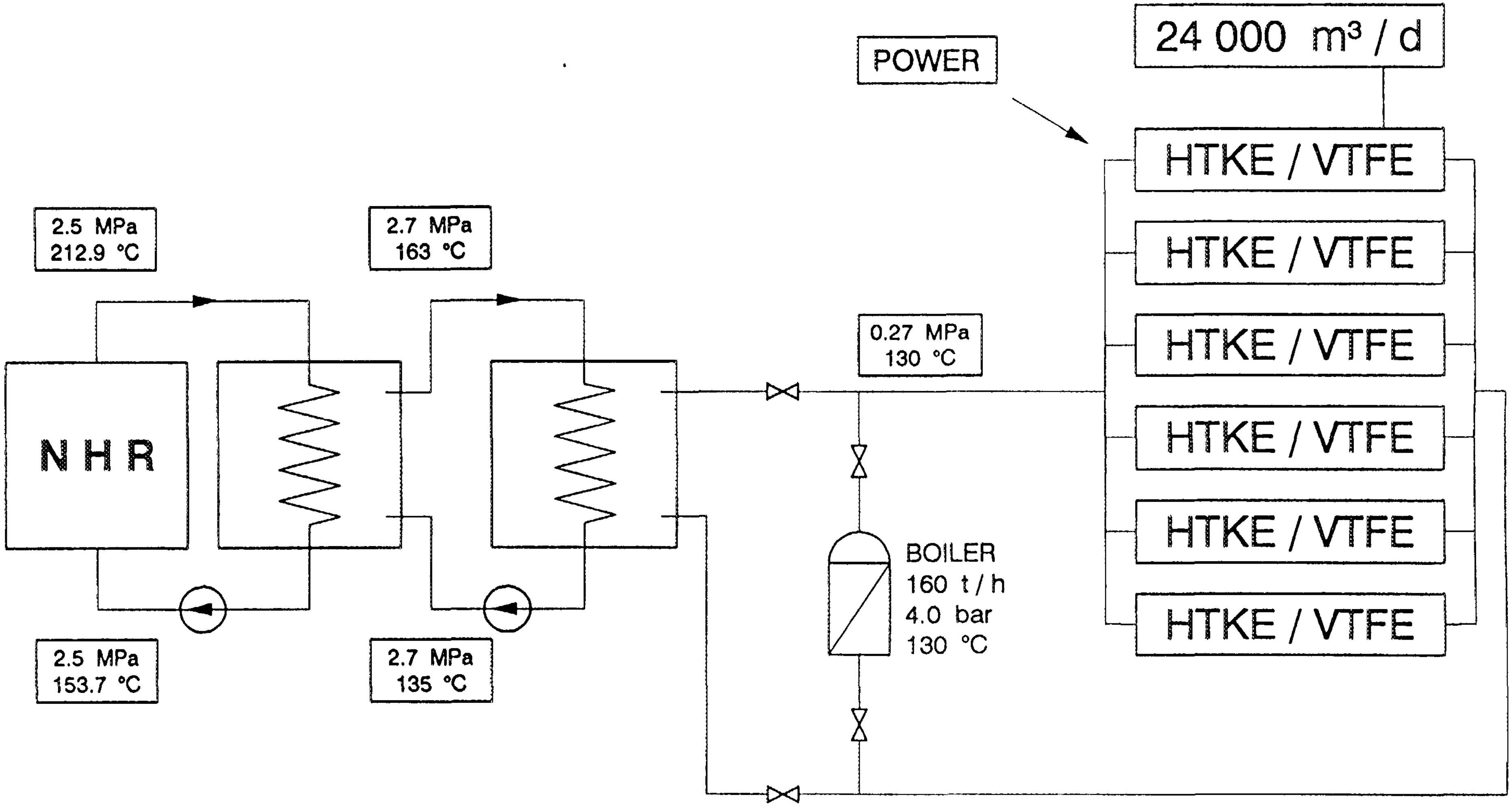
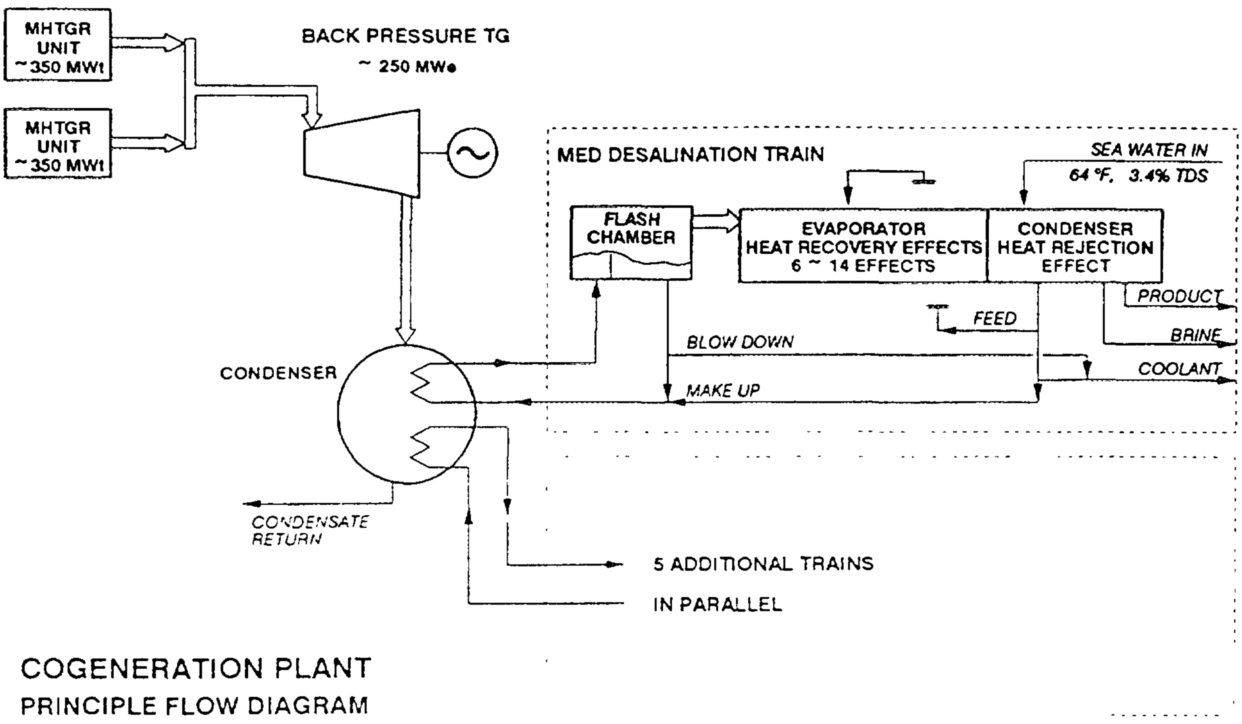
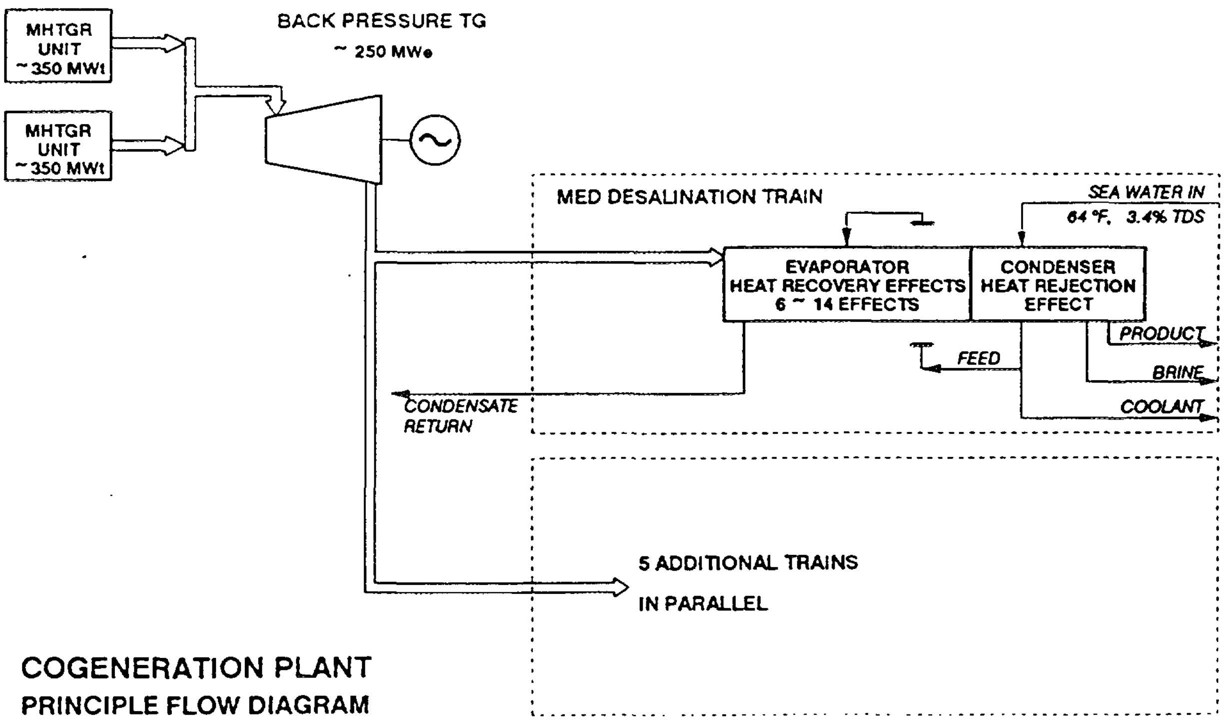


Fig. 18: *Flow diagram of heat only nuclear desalination plant*



COGENERATION PLANT
PRINCIPLE FLOW DIAGRAM
SCHEME No. 1



COGENERATION PLANT
PRINCIPLE FLOW DIAGRAM
SCHEME No. 2

Fig. 19: Alternative schemes for delivering heat to LT-MED

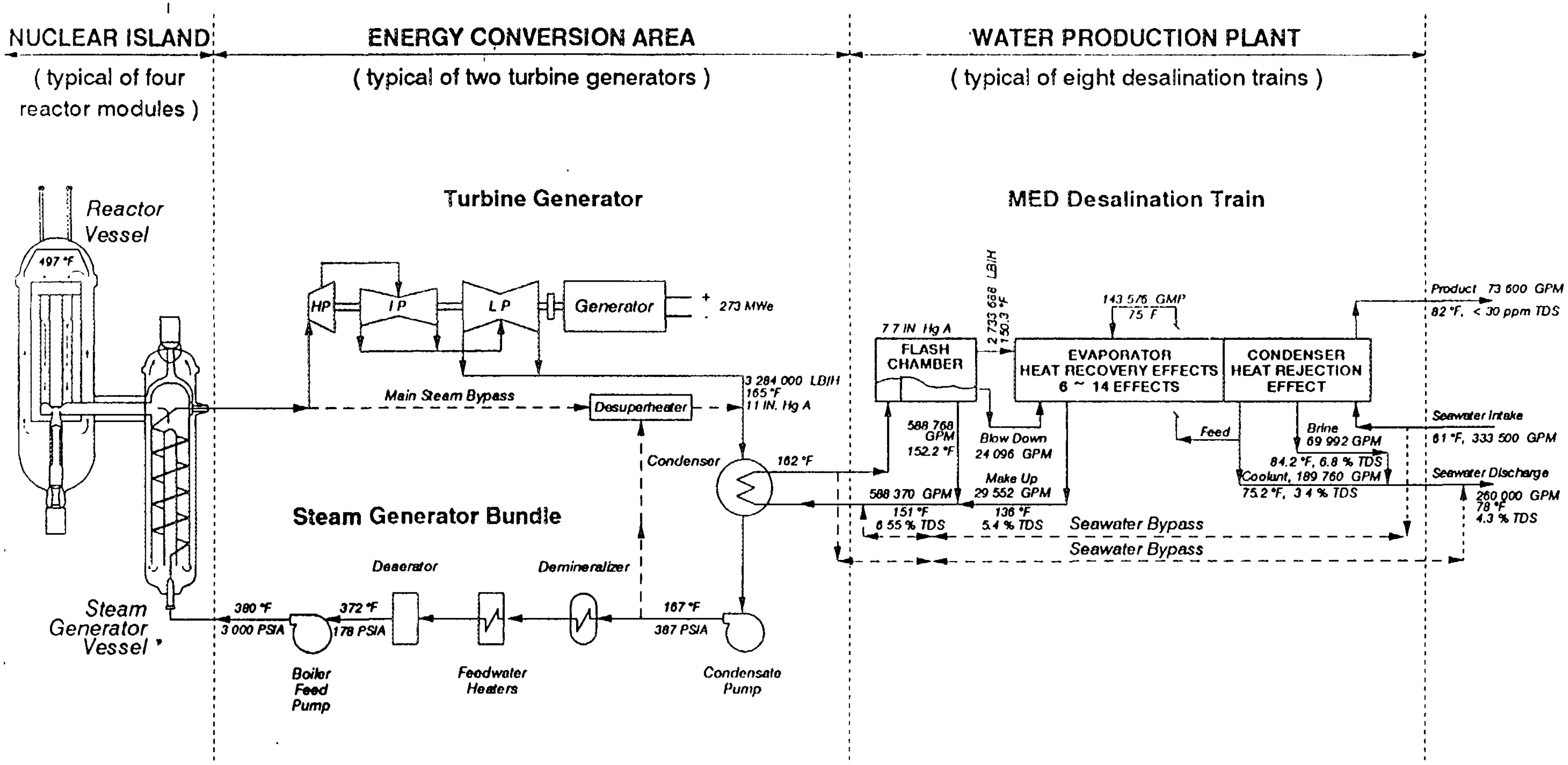


Fig. 20: MHTGR desalination plant - simplified flow diagram

The MHTGR was viewed as being particularly appropriate for such an application for the following reasons:

- The small plant size (compared with current reactor concepts) and modular configuration are more compatible with a process energy application such as desalination.
- In a cogeneration application, the impact on electrical production is reduced, compared with WCRs, due to the high initial steam conditions (17.2 MPa, 540 ^{0}C) by using the MHTGR.
- The small unit size (350 MW(t)) and passive safety characteristics of the MHTGR provide a technical basis for siting near water distribution systems.

The selection criterion for the desalination process to be coupled with MHTGR was simply to choose the process that had the lowest levelized water cost, provided that other factors did not result in any overriding negative effects. On the basis of the evaluation, the LT-HTME was selected as the reference concept to be coupled with MHTGR.

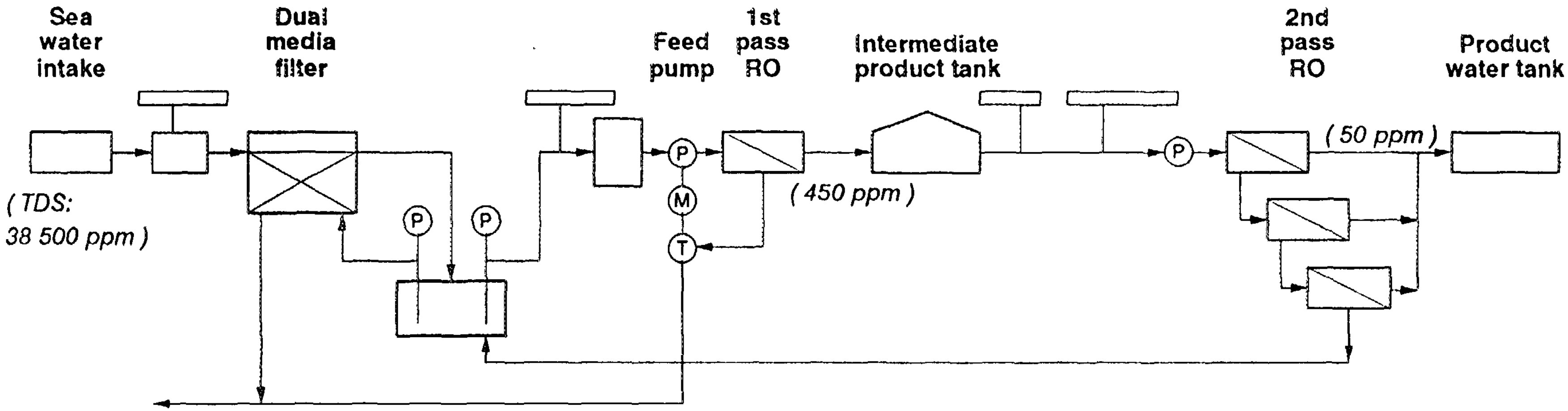
Two different methods were proposed for supplying heat to the LT-HTME process. These are referred to as Scheme 1 and Scheme 2 and are illustrated in Figure 19. In Scheme 1, turbine exhaust steam is condensed in a conventional condenser, becoming boiler feedwater. In Scheme 2, the turbine exhaust steam is fed directly to the first effect of the desalination unit. After careful technical and cost analysis of the two alternatives, the Scheme 1 steam delivery system was selected. Steam pressure and the number of effects were optimized to give the lowest water cost, yielding a turbine pressure of 37 kPa and 16 affects for the desalination plant. The reference MHTGR desalination plant features resulting from the selection and optimization processes are depicted in Figure 20. A summary of the major plant design parameters is given in Table 65.

TABLE 65: MHTGR DESALINATION PLANT DESIGN PARAMETERS

Reactor thermal power, MW(th)	1,400
Gross generator Output, MW(e)	546
Net electrical Output, MW(e)	466
Fresh water Production, m3/day	400,000
Thermal power to water plant, MW(th)	873
Water plant performance ratio	5.3
Maximum brine temperature, °C	64
Intake seawater flow m3/min	1,262
Product water TDS, ppm	< 30
Plant life, years	40
Water production availability, %	84
Power production availability, %	80

8.3.4 Coupling with LMCR

The only desalination energized by an LMCR, or indeed by any nuclear reactor, is located in the Aktau complex in Kazakhstan, which comprises a nuclear power plant, BN-350, coupled with twelve Seawater Distillate Production Plants (DPP). The Aktau complex demonstrated the benefits of a large capacity sodium cooled LMCR, and enabled studying the characteristics of joint operation of the BN-350 and desalination installation. The combination of the reactor with desalination units yielded high thermal efficiency and reliability, proving this to be a good solution to water shortages.



Electric power:	50 MWe
Water production	168 000 m^3/day (24 000 m^3/(day·unit)
(RO system:	5 kWh/m^3)

Fig. 21: *Process flow sheet for each train (4S-RO systems)*

The Central Research Institute of Electric Power Industry of (CRIEPI) Japan, has initiated a conceptual design study [49] whose purpose is to prevent desertification in the world. The Liquid Cooled Fast Reactor (LMCR) has been selected for this study for the following reasons :

- Electromagnetic pumps can be utilized in place of mechanical pumps, since the coolant has a high electrical conductivity.
- The core of a LMCR has a high internal conversion ratio, making it possible to maintain burnup over long periods without refueling. core without need of refueling for 10 years can be built based on this feature. As a result, periodic refueling would be eliminated.
- The burning rate in the core can be controlled by annular reflector outside core, taking advantage of the long mean free path of fast neutrons. This feature allows elimination of the control rod drive mechanism, which is usually inside the reactor vessel, greatly reducing the maintenance burden.
- The safety facilities of LMCRs (decay heat removal system) can be constructed with passive components. The safety function can be guaranteed without maintenance.
- The reactivity coefficient can be made negative in a core with high neutron leakage. As a result, factors producing positive reactivity insertion are completely removed in any accident, making it possible to terminate an accident by physical characteristics only.

The selected desalination process is reverse osmosis, and the water production rate is to be about 170,000 m^3/d. RO was selected because of low energy consumption, simplicity of operation, low maintenance, short start-up period and ease of partial capacity operation.

Coupling the NPP and the RO units could be done electrically or through direct mechanical coupling. The general arrangement of the nuclear desalination plant is shown in Figure 21.

8.4 COUPLING SCHEMES FOR THE PRESENT STUDY

The selection of the candidate combinations of power and water plant types depends on several factors. The controlling parameters for this analysis were water demand at each site and the maximum power unit size that could be accommodated by the projected grid capacity in the year 2005. In order to accommodate grid stability, a conventional criterion was adopted. A single power unit could not be larger than 10-15% of the projected grid size.

The five reference sites, based on 1991, data are indicated on Figure 3, and the projected grid sizes for the NACs are listed in Table 36. For convenience, these data were combined in Table 66 together with the range of maximum allowed power unit size, and the selected power unit sizes.

The energy sources considered for coupling were those discussed in Chapter 7, whose technical data are listed in Table 64. Desalination systems are those selected in Chapter 6, namely MED, RO (stand alone, contiguous and contiguous with pre-heat) and the Hybrid MED/RO and MED/VC. MSF was not considered because of the higher water cost and energy consumption as explained in Chapter 6.

For each power unit, coupling with all of the above desalination systems was considered within the following constraints:

- The adaptability of power systems to be coupled with certain desalination processes, for example the GT-MHR and diesels, are not readily adaptable to MED plants.

- Ensure diversity of reactor types, and at the same time limit the number of cases to a manageable number, because the number of possible combinations for each site is extremely large. Therefore, only representative combinations that were judged to be most practical were selected.

Table 67 shows the generic matrix for coupling the various energy sources with the desalination systems. The sub-sections below discuss the actual selections that were made in descending order of water capacity demand.

TABLE 66: PROJECTED POTABLE WATER AND PEAK LOAD DEMAND FOR THE REFERENCE SITES IN 2005

Site	Site Capacity (1000 m^3/d)	Peak Load (1) MWe	Maximum Power Unit Size(2), MWe	Selected power Unit Range MWe
Tripoli	720	5280	500 - 800	287 - 450
El-Dabaa	240	17523	700 - 2600	300 - 660
Oran	120	6800	700 - 1000	25 - 450
Zarzis	60	2260	220 - 330	25 - 48
Laayoune	24	4390	440 - 660	25

(1) National peak load

(2) Based on 10-15% - rule of thumb criterion for grid stability

8.4.1 Coupling Schemes for Tripoli (Libya)

The projections of potable water and peak power demands shown in Table 66 indicate that the need for additional potable water production capacity is more pressing than for additional electrical power capacities. Therefore, the coupling concepts which can divert more energy to water production rather than electricity production were favoured. This is more easily achieved with RO or hybrid couplings, which are not limited to the ratio of electric power to produced water. MED couplings are practically restricted to diverting only about a third of the total energy to the water plant.

The maximum allowable unit size for the Tripoli site, shown in Table 66, justifies reactors in the medium range including CANDU-6 and AP-600. However, because of the large ratio of water to power, the smaller plants (NP-300, CANDU-3 and GT-MHR) were selected. The analyzed cases also included, for comparison, medium sized gas/oil steam power plants, gas turbines, and combined cycle units. A large nuclear heat-only reactor, the AST-500, was also included. The matrix of coupling schemes selected for Tripoli is shown in Annex I.

8.4.2 Coupling Schemes for El-Dabaa (Egypt)

The projected potable water demand for El-Dabaa and peak load demand for Egypt, shown in Table 66, indicate that, unlike Tripoli, the need for additional power capacity on a country wide basis is more substantial than the need for local water production capacity. Therefore, the coupling concepts which divert less energy to water production were selected.

TABLE 67: GENERIC MATRIX OF VARIOUS ENERGY SOURCES AND DESALINATION COUPLINGS

Energy Source	MED				RO		MED/RO	MED/VC
	a	b	c	d	A	B		
Nuclear								
Steam Power Plant			I		II	II	III	
Brayton Cycle (GT-MHR)					IV	IV		
Heat Only Reactors	V	V	V	V				
Fossil								
Steam Power Plant			VI		VII	VII	VIII	
Gas Turbine			IX		X	X	XI	
Combined Cycle			XII		XIII		XIV	
Diesel			XV		XVI		XVII	XVIII
Heat Only Boiler	XIX		XIX					
Renewable								
Solar Pond	XX							

NOTES: a = Purchased electricity - with or without an intermediate isolation loop
b = Purchased electricity - with two intermediate isolation loops
c = Self-generated electricity - with or without an intermediate isolation loop
d = Self-generated electricity - with two intermediate isolation loops
A = Stand alone
B = Contiguous with or without preheat.
Key = The same Roman numbers, I - XX, are indicated also on the Tables and spread sheets in Annexes I - V for cross reference.

The maximum allowable unit size for El-Dabaa, shown in Table 66, justifies reactors in any commercial size range, including all the reactors considered in this study. However, in order to limit the number of new cases, only NP-300, CANDU-3 AP-600 and CANDU 6 were included. Only medium size combined cycles were included for comparison. The matrix of couplings selected for El-Dabaa is shown in Annex II

8.4.3 Coupling Schemes for Oran (Algeria)

The local water needs in Oran is small compared with the size of power plant that could be accommodated by the grid, which justifies large reactors sizes including all the reactors considered in this study as indicated in Table 66. However, because of the smaller ratio of water to power, the smaller plants including the NP-300, CANDU-3, GT-MHR and even the CAREM-25 were included.

Because of the smaller water demand at Oran, two concepts dedicated to water production were also included. These are a diesel generator in combination with RO and the heat only reactor HR-200 in combination with MED. The CAREM-25 is very small and, therefore, nearly all its output must be devoted to water production through RO. The matrix of couplings selected for Oran is shown in Annex III.

8.4.4. Coupling Schemes for Zarzis (Tunisia)

The projected additional potable water requirement at Zarzis and the corresponding Tunisian peak power demand, shown in Table 66, indicate that both the desalination plant capacity and maximum power plant sizes are small. Therefore, the number of different power options that may be considered is limited. However, this provides an opportunity to evaluate the dedicated heating reactors; THERMOS, LT-4 and TRIGA, and smaller fossil plants such as diesels. In addition to the heating reactors two small power plants, 4S and CAREM-25, were considered. The fossil options included: two diesel options, one coupled with RO and the other with a hybrid MED/RO plant using the exhaust for heating, a dedicated fossil boiler combined with MED, and combined cycle coupled with MED or RO. The matrix of coupling arrangements is shown in Annex IV.

8.4.5 Coupling Schemes for Laayoune (Morocco)

The projected requirement of additional potable water demand in Laayoune and the corresponding Moroccan peak power demand, indicate that the local water demand is trivial by comparison with the power plant sizes that can be accommodated, as can be seen in Table 66. The projected grid size justifies any of the reactors considered in this study (Table 64). However, the water capacity is so small that the reactors considered for the above sites would be uninteresting and would yield no new information. The small water output gives the opportunity to examine a number of novel concepts including a range of heat only reactors such as: SES-10, GEYSER and TRIGA, coupled with MED. Other novel concepts include diesels with RO and MED/VC and the solar pond which is a renewable energy source. The matrix of coupling arrangements is shown in Annex V.

9. REGIONAL DESALINATION EXPERIENCE

9.1 GENERAL

Desalination plants were introduced into the Region as early as 1926 when a land marine type desalination plant was built in Ras-Gharib oil field in Egypt. Various sizes and technologies have since been employed by NACs to satisfy their increasing demand for fresh water for both municipal and industrial purposes.

To prepare for a cost effective and technically sound desalted water master plan, the existing systems should be evaluated under the prevailing local conditions. The major objectives should include technical features, operating problems and basic cost indicators to permit quantitative and/or qualitative assessment of the following parameters.

- Operability.
- Maintainability.
- Reliability.
- Flexibility.
- Potential for modifying or upgrading treatment.
- Energy consumption.
- Environmental impact.

However, the information necessary to carry out such a detailed analysis for the Region or individual NACs is not available at present. Therefore, the results obtained from the limited available data [27, 53-55] will be complemented by world wide experience pertaining to desalting systems under similar conditions [6, 24].

9.2 REGIONAL INVENTORY OF DESALINATION PLANTS

The IDA world-wide inventory of desalting plants [6], indicated that the total Regional capacity of plants capable of producing more than 100 m^3/day of fresh water per unit (delivered or under construction as of 31 December 1989) was 900,000 m^3/day.

The total installed capacity of desalination plants in Algeria is slightly more than 176,000 m^3/d, most of which (94.5%) is utilized by the industry and power sectors. The Reverse Osmosis (RO), process makes up 44.9% of the Algerian desalination capacity, followed by Multi-Stage Flash distillation (MSF) at 34.4% of the total. Electro-dialysis (ED), Vapour Compression (VC), Multiple Effect Distillation (MED), and other processes make up the balance. Most of the Algerian inventory (53.4%) purifies brackish water.

Egypt possesses about 68,000 m^3/d total installed capacity. Seawater desalination represents 37.6% of the total. Industry and power has the largest share of desalination capacity (59.3%). RO and ED are the most used desalination processes in Egypt, representing 43.2% and 37.3% of the total, respectively.

The largest desalting capacity in the Region exists in Libya with 69.1% of the total Regional capacity. The MSF process represents two thirds of the Libyan inventory, followed by RO (20.4%). Because of low precipitation and the decline of the water table, entire coastal cities and towns in Libya are dependent on seawater desalination to satisfy their needs for drinking water. Therefore, 63.4% of the Libyan inventory is directed towards municipal uses and 78.5% of the inventory is from seawater desalination, a situation which is unique among NACs.

In Morocco, most of the existing desalination units are installed in the South (Sahara Province), and are operated by Office National de l'Eau Potable (ONEP) or Office Cherifien des

Phosphates (OCP). Drinking water is produced by ONEP while OCP produces industrial water only for supplying the boilers and treatment factories located in Phosboucraa. Industry has by far the largest share of desalination capacity in Morocco (64.9%) followed by the power sector (18.7%). Seawater desalination represents 76.8% of the inventory. The desalination capacity is dominated by MSF (62.6%) and VC (18.9%).

The Tunisian inventory is about 23,000 m^3/d, most of which is RO (41.0%). The second largest capacity is ED (26.5%) and the third is VC (18.5%). Most of the desalting capacity is directed towards industrial uses (45.4%). Municipal capacity represents only 20% of the Tunisian inventory. Brackish water purification represents 79.5% of the total capacity.

TABLE 68: DISTRIBUTION OF DESALINATION CAPACITIES BY PROCESS IN THE NORTH AFRICAN REGION AT THE END OF 1989 (m^3/d)

Process	Country						
	Algeria	Egypt	Libya	Morocco	Tunisia	Total	%
MSF	60,535	5,790	414,253	6,000	336	486,914	54.4
RO	78,976	29,292	126,512	1,006	9,397	245,183	27.4
ED	13,775	25,269	66,894	359	6,056	112,353	12.5
VC	20,885	6,200	4,039	1,816	4,220	37,160	4.1
ME	955	1,177	6,456	-	240	8,828	1.0
OTHERS	961	-	1,200	400	2,621	5,182	0.6
Total	176,087	67,728	619,354	9,581	22,870	895,620	100.0
%	19.7	7.6	69.1	1.1	2.5	100.0	

* Source Reference [6]

TABLE 69: DISTRIBUTION OF DESALINATION CAPACITIES BY END USE IN THE NORTH AFRICAN REGION AT THE END OF 1989 (m^3/d)

	Country						
User	Algeria	Egypt	Libya	Morocco	Tunisia	Total	%
Municipal	9,136	13,415	393,000	1,284	4,584	21,419	47.1
Tourism	-	11,380	1,800	294	181	13,655	1.5
Military	568	2,320	24,226	-	-	27,114	3.0
Industry	162,375	33,929	185,489	6,214	12,873	400,800	44.7
Power	4,008	5,264	9,299	1,789	2,232	22,592	2.5
Others	-	1,420	5,540	-	3,000	9,960	1.2
Total	176,087	67,728	619,354	9,581	22,870	895,620	100.0
%	19.7	7.6	69.1	1.1	2.5	100.0	

* Source Reference [6]

TABLE 70: DISTRIBUTION OF DESALTING INVENTORY IN THE NORTH AFRICAN REGION BY FEEDWATER TYPE AT THE END OF 1989 (m3/d)

Feed Water	Country						
Type	Algeria	Egypt	Libya	Morocco	Tunisia	Total	%
Sea	82,112	25,473	486,239	7,358	4,677	605,859	67.7
Brackish	93,975	42,062	131,405	2,223	18,193	287,858	32.1
Others	-	193	1,710	-	-	1,903	0.2
Total	176,087	67,728	619,354	9,581	22,870	895,620	100.0
%	19.7	7.6	69.1	1.1	2.5	100.0	

* Source Reference [6]

A summary of desalination inventory in the North African Region distributed by processes, end use, and feedwater type is presented in Tables 68 through 70. It is worth mentioning that the operational life time of desalination plants in the NAR is about 15 years. Therefore, the majority of plants built in the 1970's are no longer in operation. Thus, the actual regional inventory is less than indicated in Tables 68-70.

9.3. ENCOUNTERED PROBLEMS IN THE EXISTING DESALINATION UNITS

Vast experience has been accumulated in the operation and maintenance as well as design, construction, and commissioning of various types of desalination plants. However, only limited studies documenting this experience are available.

In Egypt, an exploratory study was carried out in 1984 to survey the performance and characteristics of different desalting systems operating in the country [54]. The study was sponsored by the Foreign Relations Coordination Unit (FRCU) of the Supreme Council Of Universities. The study sample included 23 users of desalted and demineralized water employing 29 desalting systems with a total of 46 units. The total capacity of the desalting units in the sample was 48,586 m^3/day, of which 72.4% were Ion Exchange (I.Ex), 13.8% ED, 7.1% RO, and 6.7% MSF.

The relative importance of different problems in MSF plants operating in Libya was reported in Reference [27]. The significance of these results is that MSF plants in Libya represent 46% of the total inventory of NAR.

The major problems encountered by NACs are discussed below based on data provided through various country inputs [27, 53-55], and complemented by international literature [6, 24].

9.3.1 Intake

The principal raw water source for desalting systems are: canals, groundwater wells, seawater wells, and seawater pipelines. The important problems related to intake included change of feed salinity and intake depletion, particularly in Egypt where rapid membrane failure of ED plants was attributed to varying salinity conditions of the wells [54].

Large objects must be eliminated from any feedwater stream. To this end open surface intakes are equipped with trash racks and rotating screens. A problem unique to the Mediterranean Coast is the existence of huge amounts of seaweed in seawater intake which blocks screening equipment. This problem is a major cost item which might be as high as 25% of the investment cost. Intake problems were encountered in 29% of the Libyan inventory.

9.3.2 Pre-treatment

During the operation of thermal desalination units (MSF & MED), it is important to avoid the precipitation of scale forming components. Scale deposits impose a barrier to the transfer of heat in a thermal process; block and even pierce membranes in a membrane plant (RO); and obstruct waterways and cause valves to seize-up in any kind of plant. Acidification of the feedwater with mineral acid has been used in many plants for the prevention of scale. Insufficient dosage of acid has resulted in scale deposition, and excess dosage of acid has lead to corrosion of tubes and evaporator shells. FRCU study [54] reported corrosion of acid dosing equipment. Even in well-operated plants, scale may deposit slowly. Scaling and corrosion have been the two most important problems in the Region. The Libyan study [27] indicated that both of these problems occurred in 41% of the MSF inventory in Libya. The FRCU study [54] indicated that scaling and corrosion problems had existed in all the surveyed sites with varying degrees of severity. In more recent times the operators of plants in the NACs have taken advantage of the development of modern polymer scale control additives, which have allowed satisfactory operation without problems of scaling and corrosion.

In membrane plants, successful long-term operation depends largely on correct pre-treatment of the feedwater to eliminate or minimize fouling, otherwise particulate matter will filter on the surfaces of the membrane modules and cause blockage. The major cause of problems in RO plants is the presence of finely suspended matter in seawater. In general this is done by chemical flocculation and prior removal of the flocculated suspended matter by filtration. In the case of conventional filters, chlorination has to be used to prevent biological growth. Chlorination has been used to control marine growth (shellfish etc.) in the seawater intakes of some distillation plants, but care has to be taken to avoid overdosing which could lead to the release of bromine and subsequent corrosion of venting systems. Algeria [53] and Egypt [54] reported problems in RO systems related to bacterial attack of cellulose membranes, local corrosion due to the presence of free chlorine, and rupturing of membranes due to scale.

9.3.3 Operation and Maintenance

One of the factors affecting the reliability of any process is the operator's skill and experience, and to achieve this the need for better training of operators is essential. High-temperature distillation requires careful attention to scale control and corrosion prevention methods, but nowadays this should be no problem with the availability of modern scale control additives and the experience in materials selection. The most demanding desalination process is RO, for which operators have to be trained in all aspects of pre-treatment.

A major problem in the NACs is the shortage of skilled manpower required to maintain and operate the plants, which leads to rapid failure of equipment and hence to unstable water production and consequent increase in the cost of water. This problem can be attributed to the prevailing socio-economic conditions in countries of the Region. For example the lower wages and hard living conditions in remote areas, in contrast to much higher salaries and better living conditions in the Gulf States has resulted in migration of skilled manpower from some NAC's to the richer Gulf States. In Libya [27] problems associated with personnel are ranked third, and were present in 33% of the MSF inventory operating in Libya.

Another important problem is the lack of spare parts, due to financial constraints and the lengthy and tedious procedures required in some NAC's for the importation of spare parts. Lack of preventative maintenance seems to be a major problem in many desalination plants operating in the Region [53, 54].

9.3.4 Environmental Impact

A major problem might arise from some of the chemicals used in the pre-treatment of feedwater, and possibly from corrosion products from the plant. In plants using acid-dosing as a pre-treatment, the ph of the blowdown is often quite low. The copper and iron content in blowdown can result in environmental problems. In some areas near large desalination plants equipped with copper-nickel or brass tubes, a change in algae growth has been noticed [24]. Some indications of pollution by ammonia, probably arising from fertilizer complexes, have been reported by Algeria [53].

From the experience gained by major desalination operators during the past 10 years there is no cause for concern with regard to environmental problems providing that there is careful election of chemical additives and materials of construction.

9.3.5 Energy Consumption

No reliable data exist on energy consumption of desalting units operating in the NACs. However the reported specific energy consumption of commercial systems [24] are indicated below:

ED : 8.3 kWh(e)/m^3

RO : 7-10 kWh(e)/m^3 without an energy recovery system; 4-7 kWh(e)/m^3 with an energy recovery system

MSF: depends on Gain Output Ratio (GOR). Data in Reference [24] can be correlated to give the approximate relationship: $E = 650 / (GOR)$ kWh(th)/m^3 in addition to 3.5 - 5.0 kWh(e)/m^3 for pumps.

9.3.6 Design Problems

Problems associated with design were estimated in the Libyan study [27] to occur in 19.5% of the Libyan desalination inventory. A clear example of the occurrence of design problems despite the choice of a good process is the 46,320 m^3/d RO plant built in Mostaganem (Algeria) in 1980 [56]. The unit was crippled by technical problems (defects in membranes, problems with regulation valves and with control instrumentation, etc.) and never went into full production. As a result, the real cost of produced water was at least ten times the projected cost of 0.283 US$/$m^3$, and the production was kept at 30% of the design capacity.

9.3.7 Stability Under Design Conditions

Two possible sources of instability were identified in Reference [24]. These are: the vapour compressor in a VC plant and the control equipment in any desalination plant. The Algerian Report [53] indicated vibration problems of vapor compressors in VC plants and instrumentation problems associated with flow and conductivity measurements, as well as automatic control of some plants. In this respect, some desalination plant managers recommend to avoid the use of microprocessors and prefer logical cabled cards.

9.4 ECONOMICS OF DESALINATION IN THE REGION

9.4.1 Availability of Desalination Plants

Accurate data on the availability of different desalination processes are not available at the moment. However, there are some indications that the availability of plants constructed in the 1960's has sometimes been as low as 40%, in contrast to over 90% availability of some of the newly installed plants. Recent data from Morocco [55] indicated that the availability of units operated by OCP was 70% for MSF units and 80% for VC units.

9.4.2 Cost of Desalted Water

The unit cost of desalted water is obtained by dividing the total annual costs by the output of fresh water. In the FRCU study, rather arbitrary allowances of 1.5% and 1.6% of the capital cost were made to cover the costs of general maintenance and major interim replacements, respectively. Capital cost data were obtained from users of operating units in Egypt, as well as manufacturers. The availability of the plants and the number of infrequent changes of RO and ED membrane modules were not considered. The study included unit sizes up to 4,000 m^3/day. The FRCU Study results could be correlated to yield the following general cost correlation.

$$\text{COST} = a\,(\text{TDS})^{b}\,(\text{SIZE})^{-c}$$

where:

COST = cost per m^3 produced at 1983 US$
TDS = Total Dissolved Solids in ppm
SIZE = Unit Capacity in m^3/day
a,b,c = Empirical coefficients given in Table 71

In Libya [27], the cost of produced potable water was found to be not less than 2.9 US$/$m^3$ based on subsidized fuel prices of 27 US$/ton for heavy oil and 75 US$/ton for light oil, with 0% interest rate. The relatively high cost was attributed to the low GOR of the MSF plants.

TABLE 71: VALUES OF THE COST COEFFICIENTS IN THE FRCU STUDY

Process	a	b	c
MSF	15.00	0.000	0.286
RO	2.89	0.175	0.250
ED	1.63	0.184	0.143
VC	5.34	0.000	0.143
I.Ex.	0.20	0.549	0.000

9.5 PREVIOUS ACTIVITIES RELATED TO NUCLEAR DESALINATION

The importance of nuclear energy and its application for peaceful purposes in the Region have been recognized since the early 1950's when Egypt participated in the 1st UN Conference on The Peaceful Uses Of Atomic Energy held in Geneva in August 1955. In a paper presented to the conference, the future electricity needs up to the year 2000 and the role of nuclear power was analyzed and discussed [57].

In August 1964, Egypt issued specifications for a dual purpose NPP to be built about 30 kilometers west of Alexandria along the northern coast at Sidi Kreir. The plant consisted of a 150 MW nuclear power station and a 20,000 m^3/d desalting unit to supply desalted water to an agricultural pilot area of about 10,000 acres. The primary objectives of this project were firstly to ascertain the economic feasibility of the method, and secondly to establish suitable farming techniques and cropping patterns, and ultimately to determine the conditions for the use of desalination as an economic and reliable means of water supply for future agricultural development in this area [58].

Although the nuclear power project has not been realized due to difficulties in securing financing, studies of the pilot agricultural scheme were continued. In 1969, Egypt participated in the well known Oak Ridge National Laboratory (ORNL) Study on Agro-Industrial Complexes using nuclear energy [59]. In 1971, the adaptation of a heavy water natural uranium system for a prototype reactor for water production was studied [60]. A reactor power of 50 MW(th) was chosen as a prototype to match the size of a pilot desalination plant supplying the water needs of the proposed experimental farm.

On 22 April 1973 a contract for a Middle East concept to design and construct a single purpose nuclear desalination plant [61] was signed in Cairo by Development Consultants Association (DCA). A PHWR single purpose desalination plant was defined as a result of the DCA study, which consists of a reactor designed for a thermal output of 40 MW, coupled with two MSF desalination blocks, each designed for a maximum output of 7,200 m^3/d.

In accordance with the increasing demand for fresh water and power generation, a contract was signed in the late 1970's between Libya and ATOMENERGOEXPORT (USSR) to design and construct a dual purpose nuclear power plant for electric generation and seawater desalination. A Soviet design WWER-440, with thermal power of 1,375 MW, was proposed.

The contract envisaged the construction of two units of 440 MW(e) with total power production of about 840 MW(e) and desalinated seawater production of about 80,000 m^3/day. The proposed desalination process was similar to the Aktau desalination technique of the 5-effect long tube vertical (LTV), 10-effect LTV and 34 stage MSF. The plant was supposed to be constructed in the Gulf of Sirt, but realization has been delayed.

During the 1970's and 1980's, worldwide interest in nuclear desalination declined and became less strong than other nuclear energy applications, such as electricity generation, district heating and industrial use of process steam. This had a negative effect on nuclear desalination activities in the NACs. Currently, only research reactors exist in the Region, the power of which are listed in Table 72 below.

TABLE 72: NUCLEAR RESEARCH REACTORS IN THE NORTH AFRICAN COUNTRIES

Country	Facility Code	Facility Name	Type	Power MW	Status	Const. Date	Crit. Date
Algeria	DZ-0001	NUR	Pool	1.0	Operating	1987/01	1989/03
	DZ-0002	ES-SALAAM	Tank	15.0	Operating	1987/12	1991/12
Egypt	EG-0001	ETRR-1	Tank	2.0	Operating	1958/03	1961/06
	EG-0002	ETRR-2	Pool	22.0	U. Const.	1993/12	1996/12
Libya	LY-0001	IRT-1	Pool	10.0	Operating	-	1983/03
Morocco	MA-0001	MA-R1	Pool	1.5	Planned	1995/01	1996/12
Tunisia	TN-0001	TRR-1	Pool	1.0	Planned	-	-

*Source Reference [62]

10. REGIONAL PARTICIPATION AND MANUFACTURING

10.1 GENERAL

10.1.1 Purpose and Scope of Local Participation

Every country has the overall responsibility for planning and implementation of its national nuclear power programme, including nuclear desalination. These responsibilities cannot be carried out without national participation, which in turn requires national manpower. When considering facilities for the production of potable water using nuclear energy, national or regional participation in both the nuclear plant and the water production plant must be considered. It is generally acknowledged that the nuclear plant presents the biggest challenge in this regard. However participation in the design process of the integrated facility is beneficial in terms of technology transfer. Furthermore, local manufacture of some components for the water production plant may require development of enhanced industrial capability. This is particularly true for RO systems, which include components such as RO membranes and high pressure stainless steel pumps. Nevertheless, the ability to participate in the activities and supply of materials for the nuclear plant will for the most part be sufficient to also allow a significant degree of local participation in the water production plant. Accordingly, the focus of discussion in this section is primarily on the nuclear plant.

An IAEA Guidebook [63] identified the purpose of national participation as:

i) To perform those activities and supply those goods and services which are necessary for the nuclear programme, and which have to be performed or supplied locally because importing them would not be feasible.
ii) To achieve the benefits of national participation through the performance of activities and supply of goods and services in addition to those included in the scope of (i) above.

The interest in maximum use of national resources is common to all countries, the highly industrialized as well as developing ones. The scope and level of national participation, and hence the regional participation, will depend on the national policies and infrastructures, and on the influence of the various applicable limiting factors discussed in Section 10.1.2 below. The minimum scope of national participation applicable to any country, however, would correspond to a policy of fulfilling only purpose (i) defined above.

The principal partners involved in national participation are the country's government, utilities, industry, research and development institutes and educational and training institutions. Foreign governments, suppliers and international organizations also have important roles. Table 73 contains the typical distribution of responsibility and functions among the principal partners. Needless to say co-operation among partners is essential for success.

10.1.2 Benefits, Constraints and Limitations

The main benefits expected from national and Regional participation are [63]:

- Improvement of the overall economy of the region and individual countries by increasing national production.
- Promotion of the development of national and regional industrial, technological and educational infrastructures.
- Raising of the general level of industrial qualifications, standards and capabilities.
- Development of highly qualified manpower.
- Acquisition of new technology and technical know-how.
- Creation of new employment opportunities.

TABLE 73: DIVISION OF RESPONSIBILITIES AND FUNCTIONS FOR NATIONAL PARTICIPATION

Partners	Main responsibilities and functions
Government	-Development of the nuclear power programme -Nuclear licensing and regulation -Establishment of bilateral or multilateral agreements, for the implementation of technology transfer, training, technical assistance, exchange of information and safeguards -Definition of national participation policy and strategy -Legislation for nuclear power and for promoting national participation -Survey of the available national infrastructure and its capability -Study of the feasibility of national participation in general and in detail -Planning and co-ordination of the national effort -Elaboration of procedures and methods to implement and to increase national participation -Provision of financial assistance -Establishment of national policy for quality assurance
Utility/Owner	-Definition of overall and detailed supply requirements of the nuclear power projects -Completion of commercial arrangements for project implementation -Supporting advice and assistance to the Government in its tasks and functions -Development of manpower for utility/owner's requirements
National industry	-Analysis of supply requirements, market conditions and production possibilities, in particular regarding quality, schedule and cost -Development of supply proposals -Production and supply of goods and services -Specialized and on-the-job training in the respective fields of competence -Implementation of improvements and additions to existing capability -Supporting advice and assistance to the Government in its tasks and functions
Research and development institutes	-Technical research and development in national participation areas -Technical and scientific assistance to the Government, utility and industry -Manpower development in basic and specialized fields -Practical training -National information exchange center -Supporting advice and assistance to the Government in its tasks and functions
Educational and training institutions	-Provision of basic and specialized academic education and training to professionals, technicians and craftsmen in fields of national interest -Planning and development of new national training capability according to requirements -Supporting advice and assistance to the Government in its tasks and functions
Foreign governments and suppliers	-Conclude agreements and/or supply contracts with appropriate governmental or industrial organizations -Provision of technology transfer -Provision of information and technical assistance as established in bilateral or multilateral agreements -Provision of training opportunities -Active participation, joint venture (possible)

- Reduction of foreign exchange expenditures.
- Increase of the country's and region's self-sufficiency.

National participation in a nuclear power programme is limited by the following main economic, financial, technical and political constraining factors:

- Cost of national products.
- Financing priorities.
- Investment capability.
- Adequate market size.
- Availability of qualified manpower.
- Industrial capabilities and quality standards.
- Capability of absorbing technology and know-how.
- Nuclear Safety.
- Availability of raw materials.
- Non-proliferation concerns.
- Conflict of interests between the country promoting national participation and the foreign supplier(s).

The above limiting factors are discussed in more detail in Reference [63].

10.1.3 National Participation Areas

The activities involved in nuclear power programmes are listed in Annex VI. The responsibility for the fundamental decisions on all activities must always remain within the country itself. There are certain activities for which full responsibility has to be borne by national organizations and which should be primarily executed by national manpower, whatever the contracting agreements. These are considered essential activities for national participation. Expert help from abroad could be obtained and used up to a point, but only for technical assistance and not as a complete replacement of the national effort [63].

Annex VI contains also a representative list of items of equipment and components for nuclear power plants, as well as materials for nuclear power projects. Some materials needed for a nuclear power project do not differ from those required for conventional projects, but there are others which involve a certain additional degree of complexity for their provision by national sources.

Table 74 presents a typical distribution of direct costs of a nuclear power plant and the percentage of national participation that could reasonably be expected for 40% and 70% overall participation rates. On the basis of the cost breakdown of nuclear power plants, there is strong economic incentive for national participation in equipment and component manufacture, which would amount to more than half of the direct cost of the plant.

10.2 SURVEY OF REGIONAL PARTICIPATION CAPABILITIES

10.2.1 Manpower

The purpose of an assessment of Regional manpower resources is to identify the regional labor pool which can supply the manpower for the nuclear power programme. Reference [63] identified three primary categories of manpower, namely:

- Professionals i.e. all managerial and technical personnel whose normal minimum formal educational requirement is a BS degree or equivalent.
- Technicians i.e. sub-professional level personnel who have specific technical training at an appreciable level beyond the 12th year of school, but less than the minimum educational requirement of the professional level.

- Craftsmen i.e. those skilled workers, who by combination of training and experience are well qualified to perform specific types of tasks, operate specific classes of equipment or perform specific operations.

A recent survey of the work force pyramid structure in the Arab Countries, including the NACs, indicated the following common features [64]:

- There is a large base of illiterate unskilled manpower that includes a significant number of peasants who abandoned agricultural work and migrated to large urban centers.
- There is a proportionally large number of redundant professionals, including engineers, in the top of the work force pyramid.
- There is a large deficit in Technicians in all the Arab Countries, including those classified as labor exporting countries.

The above results indicate the relatively large difference in social and economic status enjoyed by professionals versus that of technicians. The available data on the number of students in the different educational categories, and the expected future work force out of the educational system, indicate that the present unbalanced pattern of the work force in the NACs will continue in the near future (see Annex VII).

Generally, the standard of education in high schools, technical institutes, and universities in the NACs is high. There is already a pool of engineers available for nuclear power programme activities, as indicated in Annex VII. No insurmountable problems are foreseen in providing an adequate skilled labor force for construction of an NDP or NPP, provided that a high level of regional co-operation is maintained and that suppliers ensure that key supervisory personnel is available.

TABLE 74: NUCLEAR POWER PROJECT COST BREAKDOWN AND NATIONAL PARTICIPATION DISTRIBUTION

Items	Direct plant cost breakdown (%)	National participation distribution for	
		overall 40% participation (%)	overall 70% participation (%)
Project Management and Engineering	15	4	12
Construction, Erection and Commissioning	20	15	18
Construction Materials	10	8	10
Equipment and Components	55	13	30
(NSSS)	(25)	(1)	(10)
(TG)	(18)	(4)	(10)
(BOP)	(12)	(8)	(10)
Total	100%	40%	70%

Note: All number indicate orders of magnitude

10.2.2 Universities and Other Research Centers

The general quality and quantity of professional training in the universities and specialized training centers is adequate, although additional training related to the special requirements of a nuclear power programme will be necessary. There are more than twenty engineering faculties and graduate engineers of different disciplines in NACs. Most of the engineering faculties are parts of universities except the engineering schools in Algeria, Morocco, and Tunisia. A list of the number of students and teaching staff in some engineering faculties and schools in the Region, as well as the available engineering departments in the North African Universities are also shown in Annex VII.

Nuclear research and development institutes in the Region can also provide valuable training in specialized fields applicable to nuclear power owing to the orientation of their activities. For example, the available research reactors (refer to Table 72) can be utilized for training personnel that will be involved in: reactor operation, regulatory activities, fuel management, and radiation protection.

10.2.3 Engineering, Construction and Erection

There are many consulting firms in the Region that provide basic engineering and other services such as: project management and non-destructive testing. There are more than 100 consulting companies active in all fields of engineering, including desalination. Many of these firms have overseas experience, particularly in the oil-rich Gulf States. This is particularly relevant for consultants in the field of desalination. There are also numerous contractors involved in design and construction of dams, tunnels, bridges, factories, power plants, pumping stations and housing. Some of these are listed in Annex VII.

10.2.4 Regional Manufacturing Capabilities

A major goal identified by the North African countries is the achievement of eventual self-sufficiency in design, manufacturing, operation and maintenance of NPPs. To achieve this goal, an adequate supply of trained manpower, additional and improved manufacturing facilities, the necessary financial resources and strong Government commitment to the nuclear power programme are necessary.

The availability of Regional sources of services was discussed in sections 10.2.1 to 10.2.3. Evaluations of national manufacturing capabilities with respect to nuclear power and desalination equipment were carried out in some NACs [65-74] to various degrees of detail and sophistication. Therefore, Regional manufacturing capabilities are reviewed below on a country basis.

10.2.4.1 Algerian Manufacturing Capabilities

Detailed analysis of the potential for the Algerian national participation in a Regional nuclear desalination project is not available at present. However, a recent survey of Governmental boiler manufacturers in Algeria indicated that the existing heavy industries within the country are involved in manufacturing petro-chemical and power plant components. For example, local participation in the 750 MW fossil power plants constructed in Algeria reached 60% and 75% for the Ras Djint and Jijel power plants respectively [66]. For details on local manufacturing capabilities in Algeria, of some target commodities relevant to power and desalination equipment, refer to Annex VII.

Special metals and alloys such as stainless steel are not produced currently in Algeria. However, there are plans to build a large plant (AFS) for alloys production in the near future.

10.2.4.2 Egyptian Manufacturing Capabilities

A major goal of the Egyptian Government is to minimize the foreign currency expenditures associated with new developmental projects through maximizing local participation. To this end several local participation studies associated with the Egyptian nuclear power programme were carried out [67-73]. Preliminary investigation of local manufacturing capabilities of desalination equipment was also performed [74]. The main findings of these studies are summarized below.

In February 1989, a comprehensive study to assess the Development of Industrial Capability In Egypt (LOCALIZATION) was initiated by a consortium of AECL and NPPA. The project consists of three distinct programs, namely:

- The Equipment Fabrication (COMPONENT) program.
- The Fuel Technology (FUEL) program.
- The Heavy Water production program.

The LOCALIZATION study builds upon earlier studies [67, 68] related to the introduction of 4x600 MW CANDU units to the Egyptian grid by the year 2000.

An earlier study specific to desalination, that was carried out by FRCU [74], identified technical packages attractive for local manufacturing. These were:

- Direct desalting components.
- Pumping Package.
- Atmospheric and pressure vessels.
- Measurement and control.
- Others including piping, valves and fittings.

The details of the above studies, as well as, the main results obtained are depicted in Annex VIII.

10.2.4.3 Libyan Manufacturing Capabilities

Detailed analysis for the Libyan manufacturing capabilities is not available. However, under the present feasibility study, a mission was sent to Libya to compile preliminary data on the subject. The mission indicated that basic components relevant to desalination plants (such as: pumps, motors, pressure vessels, heat exchanges, etc.) are not manufactured in Libya at present.

There is, however, a reasonable industrial base for Libyan participation with other NACs in manufacturing desalination equipment. The large Iron and Steel Complex at Musrata produces most of the known steel sections such as bars, sheets, channels, beams using cold and hot rolling. The complex does not produce, however, special metals and alloys such as stainless steel.

The Organization of Engineering Industries consists of a number of modern specialized manufacturing workshops to perform casting, forging, machining, heat treatment welding. All these processes, as well as the steel products are needed in any regional manufacturing of desalination equipment. A list of candidate Libyan establishments is depicted in Annex VIII.

10.2.4.4 Moroccan Manufacturing Capabilities

Industrial capabilities in Morocco are quite developed, and can contribute to any regional programme for manufacturing of desalination equipment. Several joint venture companies, mainly with French and Belgian partners, produce components relevant to desalination plants such as: pumps, industrial boilers, valves and pipes.

There are also a number of modern workshops having links with foreign companies. These workshops are capable of performing most of the basic manufacturing process such as: machining, welding, casting, forging, plating and heat treatment. The Moroccan industrial capabilities are depicted in Annex VIII.

10.2.4.5 Tunisian Manufacturing Capabilities

In 1988, a survey of Tunisian industries was made to determine the degree of possible national participation in power plants projects. The results of the survey can be extended, with the necessary updates, to the participation in a regional nuclear desalination project.

Generally, the industrial sector has the capacity to start a manufacturing program in the following fields:

- Heat exchangers, pumps, pipes, valves.
- Tanks for water storage and chemical feeding.
- Transformers, cables, switchboards, motors, lighting and insulation.
- Measurement and control.

However, the companies differ from one another in level of participation in this program. The main results of the above study are outlined in Annex VIII.

10.3 PRE-REQUISITES FOR A SUCCESSFUL REGIONAL MANUFACTURING PROGRAMME

A pre-requisite for manufacturing nuclear and desalination equipment and systems in the Region is a comprehensive and compatible QA/QC regime. Traditionally, QA/QC and inspection standards in the Region are not indigenous and rely largely on internationally accepted standards from other countries, e.g. the appropriate ASME, BS, French, German and ISO standards. Very largely the standards used are those appropriate to the original design of the equipment, i.e., if a power station is largely of German design then German QA/QC requirements will be used for all equipment on the station.

This has led to a fragmented approach to QA/QC, not only in the region as a whole but also within each individual country. The resulting incompatibility of equipment and manufacturing standards could make it difficult to broaden the manufacturing base for nuclear desalination plans on a regional basis. The need for substantial indigenous manufacture in a postulated nuclear desalination plant means, therefore, that the North African countries should now start developing specific QA/QC codes of practice for the region. These should be acceptable, and if possible, mandatory within the region. They should be based on internationally accepted best practice. A suitable framework could be the latest edition of the IAEA QA series - IAEA 50 C-QA, IAEA 50-SG QA1- QA11 for nuclear plant and systems.

The implementation of a regional QA/QC policy will need to be backed up by a series of regional NDT (non-destructive testing) and validation laboratories to ensure inspection standards are maintained and are uniform throughout the area. These standards laboratories currently exist in Algeria and Egypt for inspection equipment and materials testing. However, they will need to be equipped to the current international state-of-the-art and will need to be expanded and supplemented to meet the expected demand if a nuclear desalination project is commenced.

All countries in the region that aspire to nuclear power have a nuclear licensing authority. As each country has developed its nuclear capabilities at different rate there are substantial differences in the levels of maturity and capability of the national licensing authorities in the region. The size of the authorities varies considerably from country to country. Particularly relevant is the status of the regulatory code in each country and its comprehension.

As no country in the Region possesses a nuclear power station and hence a regulatory code that is specifically geared for the requirements of such a plant, it follows that it is still possible to establish a regulatory framework for the region as whole without compromising the requirements of any single country. Such a regulatory code could be developed and enforced on a regional basis, especially as a number of the proposed sites for nuclear power and nuclear desalination plants lie in border areas and are likely to supply the needs of more than one country.

It is therefore recommended that a North Africa Safety Advisory Group (NASAG) could be set up to develop a Regional Safety and Licensing approach. This approach could be established on the basis of safety and fundamental and other relevant IAEA safety document (see Chapter 14). The NASAG should pay particular attention to the special needs of nuclear desalination plants insofar as it is necessary to ensure the isolation of the potable water from nuclear contamination.

The most important factor influencing the success or failure of a regional manufacturing program is the degree of regional co-operation and integration. A high degree of co-operation and integration in planning and execution of local manufacturing of power plants and desalination equipment will mean a large potential market, which in turn will make local manufacturing of a larger number of components feasible economically. In this respect, strong commitment of all the Governments of the NACs to a joint nuclear power program is essential.

In summary, there are several crucial activities that have to be addressed locally to ensure successful local participation in nuclear programs. These are:

- Establishing a competent and knowledgeable purchasing authority for any proposed plant.
- Ensuring a competent nuclear licensing authority exists with the capability of understanding any special requirements for nuclear desalination plants.
- Ensuring that any indigenous manufacturing capability can produce equipment to the appropriate quality standards.
- Ensure that any local manufacturing fits into a total overall plan for the plant and that the main suppliers of the nuclear and desalination systems are made fully aware of indigenous capabilities.
- Ensuring that an appropriate infrastructure is set up supporting the proposed plant.

Other important conditions for a successful Regional manufacturing program are:

- Standardization of nuclear desalination plants in terms of module sizes, desalination processes, nuclear island and design.
- Performance of demand and supply analysis of various packages, systems, and components within the existing and projected desalination units (fossil and nuclear).
- Survey of regional capabilities on an integrated basis with respect to:
  - Identification of potentiality
    - ready now.
    - needs modification.
    - has to be set up.
  - Performance of industrial investment planning to set priorities.
  - Performance of cost-benefit analysis.
- Development of a consistent set of governmental actions and incentives promoting Regional participation and transfer of technology.
- Ensuring that financial resources for local participation are readily available.

10.4. SUGGESTED PROPOSALS FOR THE FUTURE

To maximize the degree of integration and efficiency in implementing the regional manufacturing program, and to maximize local participation, joint venture companies could be established on the following basis:

- An engineering company to carry out:
  - System engineering.
  - Procurement of equipment.
  - Construction management.
  - QA/QC.
  - Start-up and testing.
- An equipment manufacturing and management company to carry out :
  - Component engineering.
  - Manufacturing management.
  - QA/QC.

11. COST COMPARISON

11.1 GENERAL

The costs of alternative energy supply options to be coupled to various desalination processes depend very much on the required output of the desalination plant. The costs for each combination of desalination process and energy source will vary for different locations and countries. Factors such as site specific conditions, infrastructure requirements and local sources of equipment, material and energy, will also affect comparative economic assessments of desalination with a nuclear energy source versus desalination with fossil or other energy sources.

A comprehensive analysis of energy and water cost for various energy sources and desalination processes was carried out in a recent IAEA generic study [21]. The analysis was based on a generic PWR coupled with MED or RO desalination processes. The economic comparison of MED and RO in that generic study was made by considering the maximum MED water plant capacity that could be achieved for each power plant size, and setting the RO capacity equal to that of MED.

The Cogeneration/Desalination Performance and Cost Method (CPCM) spread sheet program was developed in the course of the generic study to facilitate the computation of the levelized energy cost of the heat source and the levelized water costs. The CPCM thermodynamic and economic analysis algorithms have been tested for robustness by desalination experts, the AECL, and the IAEA. The CPCM is available in Lotus 1-2-3 or Excel Formats, compatible with either DOS or MAC operating systems.

The cost calculations in the present Regional study are based, contrary to the IAEA generic study, on the actual reactors identified in Chapter 7, for which technical and economic data were supplied by the vendors. The desalination processes were those selected in Chapter 6, and the coupling schemes for each of the reference sites were those developed in Chapter 8. For the analysis presented herein, the water plant size matched the site water demand, independent of the power plant capacity. Apart from the reactor types and the water plant size requirements, the cost comparison in the Regional study was very similar to that of the IAEA generic study [21]. Numerous improvements and performance options were added to the CPCM spread sheets. These will be discussed later in this Chapter.

In this assessment, only land based desalination and energy plants were considered, even though barge-mounted nuclear energy sources may be available and economically attractive. Financing issues have not been considered, nor have analyses been carried out on the pricing of desalted water. Such analyses will require project and country specific assumptions beyond the scope of the present economic comparison. Thus, the comparison does not include comparison of the financing schemes discussed in Chapter 12.

11.2 COST COMPARISON METHODOLOGY

There are various different methodologies available for comparative economic evaluations, ranging from the very simple to the highly sophisticated. The methodology to be applied depends mainly on the purpose of the evaluation and on the detail and reliability of the data and information available.

The most useful criterion to measure the economic merit for each combination of a desalination plant and an energy source is that of the lifetime levelized unit cost of the potable water produced, expressed in US$ per m^3. This levelized cost is obtained by dividing the sum of all the expenses related to the production of water by the total amount of water produced, where proper discounting is done using a predetermined interest or discount rate. This methodology is similar to that generally used in calculating the levelized cost of electricity for power plants. For more detail and a description of the methodology refer to the recent IAEA study [21]. In addition, however, some other criteria have to be considered as well, such as:

- Total investment and specific investment per production capacity (expressed in US$ per m^3/d).
- Value of the specific energy consumed by each unit of potable water produced.
- Local participation.
- Etc.

11.2.1 Single purpose plant

The economics of using single purpose nuclear or fossil fueled plants to supply heat (only) or electricity (only) to desalination plants can be evaluated and compared using the generally accepted constant money levelized cost methodology as recommended in Reference [75].

The procedure of calculating the levelized cost of energy from a single purpose plant is relatively simple and is based on the present value concept that takes into account the time value of money. Thus, the levelized cost of energy is the discounted cost of all expenditures associated with the design, construction, operation, maintenance, fueling, decommissioning, and waste management, divided by the discounted value of the quantities of energy produced.

Calculating the cost of potable water follows fundamentally the same procedure but in this case all expenditures associated with the desalination plant are considered, and instead of the cost of "fueling", the cost of energy delivered at the desalination plant is taken as an input. The cost of water calculated with this procedure will be at the outlet of the desalination plant, and will exclude all costs associated with storage, transport and distribution to the final consumers. These latter costs are substantial, and very much site dependent.

11.2.2 Dual purpose plant

Several methodologies have been suggested for the evaluation of the economics of dual purpose plants which cogenerate electricity and heat [24, 76-81]. The power credit method remains the preferred methodology in comparing the cost of produced water. This method selects a predetermined value for one of the products (electricity or heat) based on the cost of that product from an alternative source. This alternative can be a single purpose plant (either existing or conceptual) and the method effectively assigns an upper limit to the value of either electricity or heat. Using that value as the cost of one of the products of the dual purpose plant, the cost of the second product can be determined. In effect, the second product is credited with all of the economic benefits associated with the plant being dual purpose.

For a dual purpose plant in which electricity generation dominates, the power credit method is appropriate. This is likely to be the case when a large nuclear reactor is the heat source and it is then reasonable to assume an electricity cost equivalent to that of a single purpose electricity generating station. The net electrical output from this single purpose plant will be greater than that from the dual purpose plant, if it is assumed to be a nuclear power reactor of the same thermal output. The power credit method, as recommended in Reference [81], is adopted as the cost comparison methodology in this regional study for the purposes of calculating the cost of the energy (heat) input to the desalination plant.

For dual purpose plants, coupling with desalination plants applies only to thermal (distillation) processes, while for single purpose, electricity generating plants coupling applies only to electrically driven processes. For all currently operating dual purpose nuclear power plants, electricity is the main product with heat corresponding to not more than 10% and generally less than 5% of the thermal output. In the case of dual purpose plants coupled with desalination plants, all the shared benefits are accrued to the water production costs.

11.3 THE CPCM SPREADSHEETS

The performance and cost analyses for water/power production and cost was carried out using the Cogeneration/Desalination Performance and Cost Method (CPCM) which has been imbedded in a spreadsheet routine (EXCEL or LOTUS 1-2-3). The spreadsheet methodology allows for all cases to be compared on a side-by-side basis with common assumptions and boundary conditions. The method was developed for the general study of nuclear desalination [21]. However, numerous updates and refinements have been added in the current version of the CPCM, hereinafter referred to as CPCM-NAR, the following modifications are included:

- Pre-heat option, where the condenser outlet cooling water is used to preheat the inlet feedwater of the RO unit.
- MED/RO hybrid model, where the hot brine out of the MED is fed to the RO unit.
- Improved MED modeling to enable adjusting the plant capacity to specific water demand requirements, by adjusting the maximum brine temperature, provided that it will not exceed the 135^{0}C limit (on set of scaling).
- Generic backpressure steam turbine performance routine, to calculate the lost electric power as a function of maximum brine temperature, the limit of which is 135 ^{0}C. This routine is judged to be conservative and slightly over estimates the lost electric power associated with raising the backpressure.
- An additional backup heat source, the cost of which was added to the cost of MED. The backup unit was added to ensure the high reliability required for water production.

A flow chart showing the procedure for water and power cost calculations used in CPCM-NAR is shown in Figure 22. The procedure begins by selecting the case, i.e. the combination of the desired energy source, desalination technology(s) and coupling arrangements (spreadsheet columns) to be examined for a specific site. A large library of generic combinations (cases) have been developed representing most common types of nuclear plants and fossil plants in combination with the several desalination technologies. This includes several hybrid schemes.

An energy source power level is specified for each case, either in terms of thermal power for heat only energy sources or net electric output for power plants. Various site, performance and cost input are then specified. Site data consists of temperature and salinity conditions. Power plant input is most pertinent to steam plant information which is effected by MED couplings. Power plant cost input data enables calculation of the base (uncoupled) power cost which is used to determine the energy cost for desalination.

Desalination performance input consists of information to determine output, energy consumption and equipment size/quantity. For MED, steam conditions must be specified. This information in turn is used in the calculation of the modified power plant performance (i.e. lost electric power production as a result of raising condenser backpressure). Desalination cost input consists of information relating to the equipment cost, energy consumption and O&M cost for distillation and RO systems.

The spreadsheet first calculates the base power plant performance to establish the conditions corresponding to unmodified net output. Then from the input data for the distillation system (MED or MSF), a revised turbine condensing temperature is established and the reduction in power output is calculated (i.e. the lost electric power). At the same time the amount of steam available to the distillation plant is calculated.

The distillation calculation is performed first. A gain output ratio (GOR) is calculated from the available working temperature difference. The total water production is then calculated given the available source steam. If the water production is too low or too high, the high backpressure

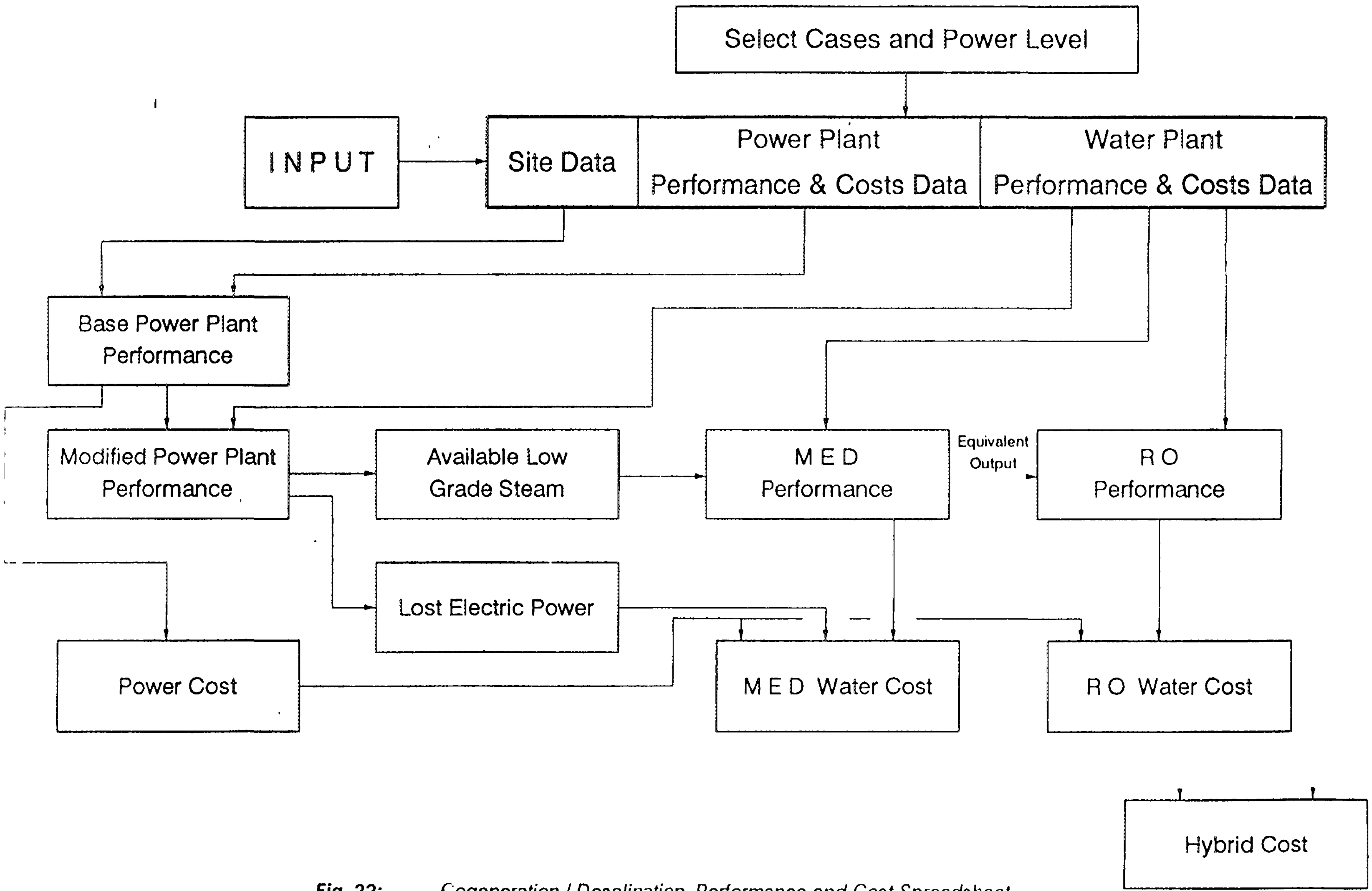


Fig. 22: *Cogeneration / Desalination Performance and Cost Spreadsheet*

condensing pressure is changed or the power plant size (or number) is changed until the water production is at the desired amount.

This is a manual operation. In addition the unit size for the distillation units must be input manually. The spreadsheet calculates the number of units required. Electrical energy consumption and maintenance conditions are also calculated as input for the cost calculation.

The RO system output can be set equal to the MED output in order to have an equivalent comparison. However, the RO output may be any value within the available electricity supply from the power plant. The unit size must be input manually. The spreadsheet calculates the number of units required. Electricity consumption and maintenance conditions for the cost analysis are likewise calculated. The CPCM-NAR has the option of preheating the feed of the RO unit. This is done by manually setting up the seawater temperature at 32 ^{0}C. The water flux was assumed to increase by 10% as a result of preheat.

In addition, the spreadsheet can be used for hybrid (MED and RO) performance and cost. For this case, the distillation unit output is established by specifying a backpressure turbine condensing temperature. The balance of the required product water is then made up by the RO unit.

From the performance calculations and the cost input, the spreadsheet calculates the base power plant power cost, the distillation system water cost and the RO system water cost by summing the annual capital, energy and O&M costs and dividing by the annual product output. The energy cost for the distillation system is equal to the revenue lost from the lost electric power. For hybrid cases, the water cost is equal to the blend of individual costs according to the amounts of distillation water and RO water. All resulting costs are presented in both detail form and summary form. In addition, a summary of investment costs are presented for the 8% interest case.

11.4 REFERENCE ECONOMIC AND PERFORMANCE ASSUMPTIONS

Reference technical and economic assumptions were adopted for this study. The technical data for the energy sources have been presented in Chapter 7 (see Table 64). The economic data for the energy sources are summarized in Table 75. The nuclear reactors' cost data in Table 75 are based on information provided by the vendors in 1991 and re-stated in January 1994 US$, by applying appropriate escalation factors where needed. Based on the pre-selection of the fossil and renewable energy sources in Chapter 7, typical costs for construction, fuel and O&M have been selected and are also presented in Table 75.

The desalination plants' assumed performance data are summarized in Tables 76 and 77 for LT-MED and RO respectively. Assumed desalination plants' construction costs are listed in Table 78. Assumed investment and O&M costs for LT-MED and RO are summarized in Table 79. It is worth mentioning that most of the performance and economic data presented in Tables 76 - 79 are extrapolated from the average cost and performance data of desalination plant sizes existing today. Therefore they are subject to some uncertainty.

The general economic parameters and their selected values are listed in Table 80. A discussion of the basis for the selected values follows below.

<u>Reference Currency and Date</u>

The reference currency is the United States dollar (US$) as of January 1994. To update the vendors cost data, which was based on January 1991 US$, appropriate escalation factors were applied.

Operation Reference Date

For the purpose of cost comparison, the operation reference date is assumed to be January 1, 2005, to tie in with the projected water demands developed for the year 2005. However, it must be born in mind that the period required for the planning and implementation of a nuclear power project may be longer than that which this reference date would permit.

TABLE 75: ASSUMED COST DATA FOR ENERGY SOURCES

Energy Plant Type	Size MWe/MWt	Type	Construction time (months)	Specific construction cost \$/kW$_e$(\$/kW$_t$)	Fuel cost mills/kW$_e$h (mills/kW$_t$h)	Specific O&M cost mills/kW$_e$h (mills/kW$_t$h)	Decommissioning allowance mills/kW$_e$h (mills/kW$_t$h)
AST-500	500 MW$_t$	PWR-heat only	60	694/kW$_t$	1.60 mills/kW$_t$h	2.75 mills/kW$_t$h	0.33 mills/kW$_t$h
GEYSER	23 MW$_t$	Pool-type heat only	36	1583/kW$_t$	3.95 mills/kW$_t$h	3.63 mills/kW$_t$h	0.33 mills/kW$_t$h
HR-200	200 MW$_t$	PWR-heat only	40	605/kW$_t$	2.59 mills/kW$_t$h	2.53 mills/kW$_t$h	0.33 mills/kW$_t$h
LT-4	80 MW$_t$	PWR-heat only	36	963/kW$_t$	5.00 mills/kW$_t$h	5.72 mills/kW$_t$h	0.33 mills/kW$_t$h
SES-10	10 MW$_t$	Pool-type heat only	36	784/kW$_t$	7.57 mills/kW$_t$h	3.63 mills/kW$_t$h	0.33 mills/kW$_t$h
THERMOS	100 MW$_t$	PWR-heat only	36	1023/kW$_t$	3.27 mills/kW$_t$h	2.31 mills/kW$_t$h	0.33 mills/kW$_t$h
TRIGA	64 MW$_t$	PWR-heat only	36	1393/kW$_t$	3.91 mills/kW$_t$h	4.18 mills/kW$_t$h	0.33 mills/kW$_t$h
AP600	600 MW$_e$	PWR	60	1839/kW$_e$	10.8 mills/kW$_e$h	8.80 mills/kW$_e$h	1.00 mills/kW$_e$h
CANDU 3	450 MW$_e$	PHWR	60	2354/kW$_e$	4.35 mills/kW$_e$h	11.00 mills/kW$_e$h	1.00 mills/kW$_e$h
CANDU 6	660 MW$_e$	PHWR	60	2265/kW$_e$	3.80 mills/kW$_e$h	9.24 mills/kW$_e$h	1.00 mills/kW$_e$h
CAREM-25	25 MW$_e$	PWR	48	2200/kW$_e$	16.80 mills/kW$_e$h	8.80 mills/kW$_e$h	1.00 mills/kW$_e$h
NP-300	300 MW$_e$	PWR	60	2420/kW$_e$	13.89 mills/kW$_e$h	13.09 mills/kW$_e$h	1.00 mills/kW$_e$h
GT-MHR	287 MW$_e$	HTGR-Gas turbine	48	2222/kW$_e$	9.20 mills/kW$_e$h	8.65 mills/kW$_e$h	1.00 mills/kW$_e$h
4S	48 MW$_e$	LMCR	24	2970/kW$_e$	25.00 mills/kW$_e$h	11.96 mills/kW$_e$h	1.00 mills/kW$_e$h
Fossil boiler	80 MW$_t$ 36 MW$_t$	Gas fired boiler heat only	18	440/kW$_t$	9.11 mills/kW$_t$h	13.20 mills/kW$_t$h	-
Fossil Generator	600 MW$_e$	Gas fired steam turbine	48	1320/kW$_e$	22.77 mills/kW$_e$h	3.30 mills/kW$_e$h	-
Gas turbine	175 MW$_e$	Gas turbine	24	440/kW$_e$	27.60 mills/kW$_e$h	6.60 mills/kW$_e$h	-
Combined cycle	450 MW$_e$	Gas turbine Steam turbine	36	660/kW$_e$	18.21 mills/kW$_e$h	5.50 mills/kW$_e$h	-
Diesel	25 MW$_e$	Diesel	18	1100/kW$_e$	19.80 mills/kW$_e$h	7.70 mills/kW$_e$h	-
Solar Pond	50 MW$_t$	Solar Pond	18	1885/kW$_t$	-	2.53 mills/kW$_t$	

TABLE 76: ASSUMED LT-MED PERFORMANCE DATA

Average cooling water temperature	21 °C
Design cooling water temperature	27 °C
Condenser temperature range	5 °C
Condenser approach temperature	2 °C
Minimum condensing temperature	34 °C
Seawater pump head	1.7 bar
Seawater pump efficiency	90%
Specific electric power consumption	0.083 kW(e)/(m^3/d)
Planned outage rate	3%
Unplanned outage rate	6.5%
Backup heat source availability	90%

TABLE 77: ASSUMED RO PERFORMANCE DATA

Average cooling water temperature	21 °C
Design cooling water temperature	18 °C
Number of stages	1
Contiguous RO preheat temperature	32 °C
Increase in water flux due to preheat	10%
Seawater pump head	1.7 bar
Seawater pump efficiency	90%
Booster pump head	3.3 bar
Booster pump efficiency	90%
High head pump pressure rise	82 bar
High head pump efficiency	96.5%
Other specific power use	0.408 kW(e)/(m^3/d)

TABLE 78: DESALINATION PLANT CONSTRUCTION COST ASSUMPTIONS

Process	Unit Size m^3/d	Number of Effects or Stages	Specific Unit [a] Base Cost US$($m^3$/d)
MED	2000 - 12000	≤28	1680
	24000 - 48000	<24	1440
	24000 - 48000	≥24	1680
MED/VC	24000	8	1650
RO	24,000	1	1125

a) Specific unit base cost excludes:

- Contingency
- Interest during construction
- Water intake/outfall structures
- Owners cost
- Intermediate loop cost

TABLE 79: ASSUMED COST DATA FOR THE DESALINATION PLANTS

	MED	RO
1. Investment Costs		
Base Unit Cost	Table 78	Table 78
Corrections for Unit Size	0.9	-
Contingency	10%	10%
Owners Cost	5%	5%
Back-up unit cost, US$/MW(t)	55000	N/A
	5000 (Heat only)	
2. O&M Costs		
Average Management Salary, US$/year	66000	66000
Average Labour Salary, US$/year	29700	29700
Spare Parts, US$/$m^3$	0.04	0.03
Chemicals, US$/$m^3$	0.02	0.07
O&M Insurance cost, % Capt. cost	0.5	0.5
Membrane replacement without preheat, US$/$m^3$	N/A	0.12
Membrane replacement with preheat, US$/$m^3$	N/A	0.11

TABLE 80: MAIN ECONOMIC AND PERFORMANCE PARAMETERS

Parameter	Reference value	Sensitivity values
Reference currency	US$	
Currency reference date	1 January 1994	
Operation reference date	1 January 2005	
Economic life	30 years	
Lifetime average load factors - nuclear and fossil plants - diesel engines and heat only plants - desalination plants	 80% 90% 91%	 - -
Real escalation rates in oil price	2%	3%
Real interest and discount rates	8%	5% and 10%
Crude oil price (FOB)	15 US$/bbl	20 US$/bbl
Crude oil transport cost	0.50 US$/bbl	
Price of electricity from grid	50 mills/kWh	40 and 60 mills/kWh
Product water guideline	WHO	
Average cooling water temperature	21 °C	
Power plant design cooling water temp.	27 °C	
RO process design cooling water temp.	18 °C	
Seawater total dissolved solids	38,500 ppm	
Energy plant construction cost	Table 75	
Energy plant O & M cost	Table 75	
Desalination plant construction cost	Table 78	
Desalination plant O & M cost	Table 79	

Construction Lead Time

The construction lead time is the time period between the first pouring of concrete and the start of operation. Thus, in the case of a nuclear project with a construction lead time of five years, the construction start must be no later than January 1, 2000 to meet the operation date of January 1, 2005. For construction to start effectively in January 2000, all previous studies and activities, such as feasibility study, site selection and qualification, acquisition (bidding, contracting), financing arrangements, international agreements, licensing, site preparation, project organization, would have to be completed by the end of 1999. The construction lead time ranges from a 60-month duration for the nuclear plant to an 12 month period for a gas/oil boiler.

Specific Construction Costs

Tables 75 and 78 show the specific construction costs for energy and desalination plants, respectively, re-stated in 1994 US$. It is assumed that there has been no increase in specific construction costs of power plants and desalination equipment, i.e. 0% escalation rate was assumed. Because the construction cost data were based on experience in industrialized countries, a 10% increase in the base construction cost has been included to allow for the added costs of installing such plants in the NACs, similar to that which was applied in a recent Egyptian feasibility study [82].

Economic Life

The economic life is the period of time after which a plant or facility is expected to be definitely shut down because of physical deterioration of the plant to the extent that it cannot sustain continuous operation at high load factors, or because of technical obsolescence. The economic life of a power plant or a desalination plant does not necessarily coincide with the technical or design life; however, the time considered for the economic life of a plant never exceeds its technical or design life. In this cost comparison, an economic life of 30 years is used for all plants, consistent with current assumptions adopted by IAEA [83] and OECD/NEA [84] for the economic assessment of power plants. In the case of gas turbines, since the technical lives are not expected to be longer than 15 years, replacements of the turbines will be necessary to allow for continuing operation of the desalination plant beyond year 15 from the operation date.

Currently there is insufficient experience with modern RO and MED to firmly justify an economic life of 30 years. However, this assumption should not be unreasonable for either type of plant. In an RO plant, the shortest life components are the membranes and filters which are changed on a regular interval. Pumps, vessels and piping have a 30 year life. MED vessels and piping are similar to MSF plants of which some units are now approaching a 30 year life. MED systems with aluminum tubes must anticipate retubing on a 15 year interval. Titanium or copper-nickel tubes may last 30 years.

Load Factor

An average lifetime load factor of 80% is assumed for all power plants, except for diesel engines, where 90% is taken. For the desalination plants, the assumed average lifetime load factor is 91%.

Real Interest Rate

Real interest rates used in many industrialized and developing countries range from 5% to 10% according to IAEA and OECD/NEA studies [83-84]. In this cost comparison, 8% is considered as the reference value for the North African Region, with 5% and 10% being used for the sensitivity analysis.

Operating and Maintenance Costs

Tables 75 and Table 79 show the operating and maintenance costs, for the energy plants and desalination plants respectively and re-stated in 1994 US$. The O&M costs are assumed to have increased by 10% for power plants. For desalination plants, it is assumed that the management and labour costs are increased by 10%, while the costs of the consumable materials remains unchanged from the January 1991 estimates.

Fuel Costs

The cost of nuclear fuel has been declining in the last decade and has now been stabilized; no real cost increase for nuclear fuel is currently foreseen [84-85]. For the regional assessment, the nuclear fueling costs are based on the responses to the IAEA questionnaire in 1991, summarized in Table 75.

The current price of crude oil in the spot market is around 15 US$ per barrel. Based on the projections made by OECD/NEA [84], crude oil prices are expected to escalate at 2% annually in real terms. Thus, for the reference case cost comparison, it is assumed that the delivered price of fuel oil is 15 US$ per barrel, with 2% per annum real increase. For the sensitivity analysis, a 3% annual real escalation and/or an oil price of 20 US$ per bbl were used. It is also assumed that the prices of natural gas and fuel-oil will be governed by and equivalent to the price of crude oil in heating value equivalents.

Spent Fuel Management and Storage Cost

The spent fuel management and storage costs for nuclear reactors are those included in vendors' responses to the IAEA questionnaire in 1991.

Nuclear Decommissioning Cost

Nuclear decommissioning costs are based on a standard provision of 1.0 mill/kWeh, reflecting the current practice in the United States.

Purchase Price of Electricity

For heat only nuclear or fossil plants, the cost of purchased electricity from the grid for plant equipment operation is assumed to be 50 mills/kWeh (January 1994 US$) for the reference case at a real interest rate of 8%. For the cases using 5% and 10% real interest rates, the prices of electricity are assumed to be 40 and 60 mills/kWeh respectively.

Economy of Scale

Various unit sizes of desalination plants are currently available, up to 48,000 m^3/d modules. However, since reliable cost data for 24,000 m^3/d unit size is available only, an adjustment factor of 0.9 has been used to extrapolate the specific cost for 48,000 m^3/d modules, reflecting the potential savings in using larger sized units.

Multiple Unit Savings

In order to capture the multiple-units savings, the cost reduction factors shown in Table 81 were assumed, resulting in a maximum saving of 27.5% per unit when 14 or more units are installed at the same location.

TABLE 81: COST REDUCTION FACTORS FOR DESALINATION PLANTS WITH MULTIPLE UNITS

Number of Units	Factor
1	1.000
2	0.983
3	0.959
4	0.935
5	0.912
6	0.888
7	0.866
8	0.844
9	0.823
10	0.802
11	0.782
12	0.763
13	0.744
14 or more	0.725

Product Water Guideline

The product water in the NACs is expected to meet the World Health Organization (WHO) guidelines for drinking water. A single stage RO will be able to meet WHO guidelines, assuming membranes will be replaced every five years, resulting in 400 ppm TDS, and 250 ppm of chlorides.

Average Cooling Water Temperature

Based on the available data for the identified sites, the cooling water temperature is in the range of 14 °C to 28 °C. For the purpose of this cost comparison, a reference cooling water temperature of 21 °C is used. The effect of increases and decreases in the cooling water temperature is examined in the sensitivity analysis. It is expected that each 1 °C increase/decrease in the cooling water temperature will result in about 1% increase/decrease in the water production using RO. Changes in the cooling water temperature will affect the water production using MED in a similar way, perhaps even higher.

MED Design Cooling Water Temperature

The power plant design cooling water temperature is assumed to be 27 °C. For those reactors that have design temperatures different from 27 °C, adjustments to the net electrical outputs are made accordingly.

RO Plant Design Cooling Water Temperature

The design cooling water temperature for the RO plant is assumed to be 18 °C. For contiguous RO with preheat, cooling water temperature was set to 32 °C with a corresponding increase in water flux of 10%.

Seawater Total Dissolved Solids

Even though the site data show a range of seawater total dissolved solids, for cost comparison purposes the total dissolved solids are assumed to be 38,500 ppm. A sensitivity analysis of changes in the seawater total dissolved solids has been performed. The seawater total dissolved solids for sites in Egypt are higher, while those for sites in Morocco are lower than this reference value.

11.5 RESULTS WITH REFERENCE ASSUMPTIONS

For single purpose electricity (or heat) only generating plants, the levelized energy costs are obtained by dividing the sum of the levelized annual costs, for capital, operation and maintenance, fueling and decommissioning allowance, of the power plant by the average annual production of electricity (or heat). The resulting levelized energy cost, expressed in mills/kWh(e) (or mills/kWh(t)), is used as an input to calculate the energy component of the levelized water cost.

For dual purpose plants, the levelized electricity cost is calculated first, and then used to calculate the value for the distillation plant. This value is taken to be the revenue that would have accrued from lost electricity generation (due to the delivery of heat) in accordance with the power credit method used. The levelized electricity and heat costs for the various selected energy sources in the different sites are shown in Tables 82 and Table 83. Detailed results are found in the spreadsheets in Annexes I - V.

The desalted water costs are obtained by dividing the sum of the annual costs, for levelized capital costs, expenses on various energies, operation and maintenance, current expenses such as insurance and taxes, and decommissioning allowance, by the average annual production of water. The resulting levelized water costs in US\$/m^3 at the desalination plant outlet are summarized in Table 84. Figures 23 - 27 show the water costs of the various options considered for each site. The results indicate that water production through the utilization of heat only reactors yields much higher water costs than dual purpose (electricity and heat) and single purpose (electricity only) reactors, confirming the results obtained in the IAEA generic study [21]. Contiguous RO appears also to be the most economic desalination process.

The most economic combinations of nuclear/desalination and fossil/desalination for each site are shown in Table 85. It is clear from the Table that the levelized water costs of fossil and nuclear options are in similar range for the base case i.e. 8% annual discount rate, US\$ 15.5/bbl oil price including transportation cost, and 2% real annual escalation in oil price. The average costs of produced water in the various sites by the nuclear and fossil options are shown in Table 85. It is clear from the Table that under the assumptions made for the various combination in each site that the nuclear option is slightly cheaper than the fossil option for Oran (120,000 m^3/d) and Zarzis (60,000 m^3/d). The opposite trend is noticed for the larger sizes in Tripoli (720,000 m^3/d) and El-Dabaa (240,000 m^3/d).

For the Moroccan site, Laayoune (24,000 m^3/d), the fossil option is clearly much cheaper than the selected nuclear heating reactors. However, extrapolating from the results obtained for the other sites, the selection of an electricity only nuclear option (e.g. CAREM-25) coupled with contiguous RO would have yielded a water cost of about US\$ 0.91/m^3.

From the levelized water cost point of view, the utilization of these selected combinations of nuclear reactors and contiguous RO plants would be competitive with fossil fired plants (mostly combined cycle) coupled with the same desalination process. Other combinations may yield different results, therefore, a careful detailed analysis will be required before major commitments are made towards a nuclear desalination programme in each of the NACs.

Table 82: LEVELIZED ELECTRICITY COSTS US CENTS/KW(e)H

Primary Energy	Plants	Power MW(e)	5%/y real interest	8%/y real interest	10%/y real interest
Nuclear	CAREM-25	25	4.9	5.9	6.7
	4S	48	6.7	7.9	8.7
	GT-MHR	287	4.2	5.2	5.9
	NP-300	300	5.3	6.5	7.4
	CANDU-3	450	4.1	5.2	6.2
	AP-600	600	4.0	4.9	5.6
	CANDU-6	660	3.8	4.9	5.7
Fossil	Diesel	25	5.0	5.2	5.4
	Diesel	30	5.0	5.2	5.4
	Gas Turbine	125	5.8	5.9	6.0
	Gas Turbine	2x175	5.7	5.7	5.8
	Combined Cycle	200	4.3	4.5	4.6
	Combined Cycle	350	4.3	4.5	4.6
	Combined Cycle	450	4.2	4.4	4.5
	Steam Turbine	600	5.4	5.9	6.3

Table 83: LEVELIZED ENERGY COSTS FOR HEATING PLANTS US CENTS/KW(t)H

Primary Energy	Plants	Power MW(t)	Heat cost at real interest rate of		
			5%/y	8%/y	10%/y
Nuclear	SES-10	6 x 10	1.89	2.19	2.43
	GEYSER	2 x 23	2.23	2.84	3.30
	TRIGA	32; 64	2.11	2.64	3.05
	LT-4	80	2.00	2.37	2.65
	THERMOS	100	1.54	1.93	2.23
	HR-200	200	1.12	1.37	1.56
	AST-500	2 X 500	1.20	1.53	1.79
Non - Nuclear	Solar Pond	50	1.86	2.50	2.97
	Gas Boiler	36; 80	2.92	3.06	3.17

TABLE 84: SUMMARY OF LEVELIZED WATER COSTS

TABLE	SUMMARY OF WATER COSTS									
(All costs in U S Jan 94 $/CU M , WHO water quality standard)										
CASE					BASE CASE			SENSITIVITY OF FUEL COSTS		SENSITIVITY OF PREHEAT
ECONOMIC PARAMETERS:										
Gas price , $/BOE					15.5	15.5	15.5	20.5	20.5	15.5
Fuel annual real escalation, %/a					2	2	2	2	3	2
Real interest rate, %/a					8	5	10	8	8	8
PLANT CHRACTERISTICS.										
	Energy sources	Size	Desalination processes	Water output (CU.M/D)						
TRIPOLI, LIBYA										
L-1	NP-300	2*300MWe	MED	737341	1.01	0.79	1.19	1.01	1.01	
L-1	NP-300	2*300MWe	RO-SA	737341	0.89	0.73	1.01	0.89	0.89	
L-1	NP-300	2*300MWe	RO-CO	737341	0.87	0.72	0.98	0.87	0.87	0.8
L-2	NP-300	2*300MWe	MED/RO HYBRID	720000	0.87	0.71	0.99	0.87	0.87	
L-3	CANDU-3	450MWe	MED	686586	0.95	0.72	1.13	0.95	0.95	
L-3	CANDU-3	450MWe	RO-SA	686586	0.83	0.67	0.95	0.83	0.83	
L-3	CANDU-3	450MWe	RO-CO	686586	0.8	0.66	0.92	0.8	0.8	0.74
L-4	CANDU-3	450MWe	MED/RO HYBRID	720000	0.83	0.66	0.96	0.83	0.83	
L-5	GT-MHR	287MWe	RO-CO	720000	0.73	0.6	0.84	0.73	0.73	0.73
L-6	STEAM TURBINE	600MWe	MED	667170	0.99	0.83	1.13	1.09	1.19	
L-6	STEAM TURBINE	600MWe	RO-SA	667170	0.86	0.74	0.96	0.92	0.98	
L-6	STEAM TURBINE	600MWe	RO-CO	667170	0.84	0.72	0.93	0.9	0.96	0.77
L-7	GAS TURBINE	2*175MWe	MED/RO HYBRID	720000	0.7	0.6	0.78	0.76	0.81	
L-8	COMBINED CYCLE	450MWe	MED/RO HYBRID	720000	0.74	0.64	0.82	0.79	0.84	
L-9	AST-500	2*500MWt	MED	638809	1.23	0.94	1.47	1.23	1.23	
EL-DABAA, EGYPT										
E-1	NP-300	300MWe	MED	247246	1.07	0.83	1.25	1.07	1.07	
E-1	NP-300	300MWe	RO-SA	247246	0.92	0.76	1.04	0.92	0.92	
E-1	NP-300	300MWe	RO-CO	247246	0.89	0.74	1	0.89	0.89	0.82
E-2	NP-300	300MWe	MED/RO HYBRID	240000	1.04	0.82	1.2	1.04	1.04	
E-3	CANDU-3	450MWe	MED	251184	1	0.76	1.18	1	1	
E-3	CANDU-3	450MWe	RO-SA	251184	0.85	0.7	0.97	0.85	0.85	
E-3	CANDU-3	450MWe	RO-CO	251184	0.82	0.68	0.93	0.82	0.82	0.76
E-4	AP-600	600MWe	MED	272928	1	0.77	1.17	1	1	
E-4	AP-600	600MWe	RO-SA	272928	0.82	0.68	0.93	0.82	0.82	
E-4	AP-600	600MWe	RO-CO	272928	0.8	0.66	0.9	0.8	0.8	0.74
E-5	CANDU-6	660MWe	MED	270382	1.06	0.8	1.26	1.06	1.06	
E-5	CANDU-6	660MWe	RO-SA	270382	0.82	0.67	0.94	0.82	0.82	
E-5	CANDU-6	660MWe	RO-CO	270382	0.8	0.65	0.9	0.8	0.8	0.74
E-6	COMBINED CYCLE	450MWe	MED/RO HYBRID	240000	0.83	0.7	0.94	0.89	0.94	
E-7	COMBINED CYCLE	450MWe	RO-SA	240000	0.81	0.7	0.89	0.86	0.91	
E-7	COMBINED CYCLE	450MWe	RO-CO	240000	0.78	0.68	0.86	0.83	0.87	0.73
ORAN, ALGERIA										
A-1	NP-300	300MWe	MED	132882	1.21	0.94	1.42	1.21	1.21	
A-1	NP-300	300MWe	RO-SA	132882	0.97	0.81	1.1	0.97	0.97	
A-1	NP-300	300MWe	RO-CO	132882	0.93	0.78	1.05	0.93	0.93	0.86
A-2	NP-300	300MWe	MED/RO HYBRID	120000	1.28	1.01	1.49	1.28	1.28	
A-3	CANDU-3	450MWe	MED	113897	1.44	1.09	1.71	1.44	1.44	
A-3	CANDU-3	450MWe	RO-SA	113897	0.92	0.75	1.05	0.92	0.92	
A-3	CANDU-3	450MWe	RO-CO	113897	0.88	0.73	1	0.88	0.88	0.81
A-4	GT-MHR	287MWe	RO-CO	120000	0.79	0.66	0.9	0.79	0.79	0.79
A-5	CAREM-25	25MWe	RO-CO	120000	0.84	0.7	0.94	0.84	0.84	0.84
A-6	GAS TURBINE	125MWe	MED	115832	0.82	0.65	0.95	0.86	0.89	
A-6	GAS TURBINE	125MWe	RO-SA	115832	0.95	0.84	1.04	1.02	1.1	
A-6	GAS TURBINE	125MWe	RO-CO	115832	0.91	0.81	0.99	0.99	1.06	0.85
A-7	COMBINED CYCLE	350MWe	MED	129871	0.91	0.74	1.04	0.97	1.03	
A-7	COMBINED CYCLE	350MWe	RO-SA	129871	0.87	0.75	0.96	0.92	0.96	
A-7	COMBINED CYCLE	350MWe	RO-CO	129871	0.83	0.73	0.91	0.88	0.93	0.78
A-8	DIESEL	30MWe	RO-SA	120000	0.91	0.79	1	0.96	1.01	
A-9	HR-200	200MWt	MED	111428	1.43	1.14	1.67	1.43	1.43	
ZARZIS, TUNISIA										
T-1	THERMOS	100MWt	MED	60142	1.73	1.35	2.03	1.73	1.73	
T-2	LT-4	80MWt	MED	60123	1.68	1.35	1.94	1.68	1.68	
T-3	TRIGA	64MWt	MED	48649	1.78	1.39	2.07	1.78	1.78	
T-4	4S	48MWe	RO-CO	60000	0.96	0.82	1.08	0.96	0.96	0.96
T-5	CAREM-25	25MWe	RO-CO	60000	0.87	0.73	0.98	0.87	0.87	0.87
T-6	COMBINED CYCLE	200MWe	MED	60128	0.96	0.8	1.09	1.02	1.08	
T-6	COMBINED CYCLE	200MWe	RO-SA	60128	0.93	0.8	1.03	0.98	1.03	
T-6	COMBINED CYCLE	200MWe	RO-CO	60128	0.89	0.77	0.97	0.93	0.98	0.81
T-7	DIESEL	25MWe	RO-SA	60000	0.97	0.84	1.07	1.02	1.08	
T-8	DIESEL	25MWe	MED/RO HYBRID	60000	0.92	0.78	1.03	0.96	1	
T-9	FOSSIL BOILER	80MWt	MED	60811	1.93	1.7	2.11	2.08	2.23	
LAAYOUNE, MOROCCO										
M-1	SES-10	6*10MWt	MED	23525	2.37	1.97	2.68	2.37	2.37	
M-2	GEYSER	2*23MWt	MED	23928	2.35	1.85	2.73	2.35	2.35	
M-3	TRIGA	36MWt	MED	24034	1.98	1.56	2.3	1.98	1.98	
M-4	GAS BOILER	36MWt	MED	24034	2.17	1.92	2.36	2.34	2.51	
M-5	DIESEL	25MWe	RO-SA	24000	1.04	0.91	1.13	1.09	1.14	
M-6	DIESEL	25MWe	MED/VC	24000	1.33	1.15	1.47	1.41	1.48	
M-7	SOLAR POND	50MWt	MED	24128	2.2	1.68	2.6	2.2	2.2	

(Data given in this table are only indicative)

TABLE 85: MOST ECONOMIC CASES OF NUCLEAR AND FOSSIL COUPLINGS

Plant Size $10^3 m^3/d$	Location	Economic Couplings [1]				Average $\$/m^3$
		Nuclear	Water Cost $\$/m^3$	Fossil	Water Cost $\$/m^3$	
720	Tripoli	GT-MHR/RO-C[2]	0.73	GT/Hybrid	0.70	0.715
240	El-Dabaa	CANDU-6/RO-C	0.80	CC/RO-C	0.78	0.790
120	Oran	GT-MHR/RO-C[2]	0.79	CC/RO-C [3]	0.83	0.810
60	Zarzis	CAREM-25/RO-C[2]	0.87	CC/RO-C	0.89	0.880
24	Laayoune	- [4]	-	Diesel/RO-C	1.04	-

(Data given in this table are only indicative)

(1) Base case: 8% interest rate, 2% oil price escalation and US$15.5/bbl oil price including cost of transportation.

(2) Preheat is used.

(3) GT/MED will give slightly lower costs of US$ 0.82/m³. However, this combinaiton was chosen to facilitate comparison with other combinations in the Table.

(4) All selected reactors for this site were heat only reactors.

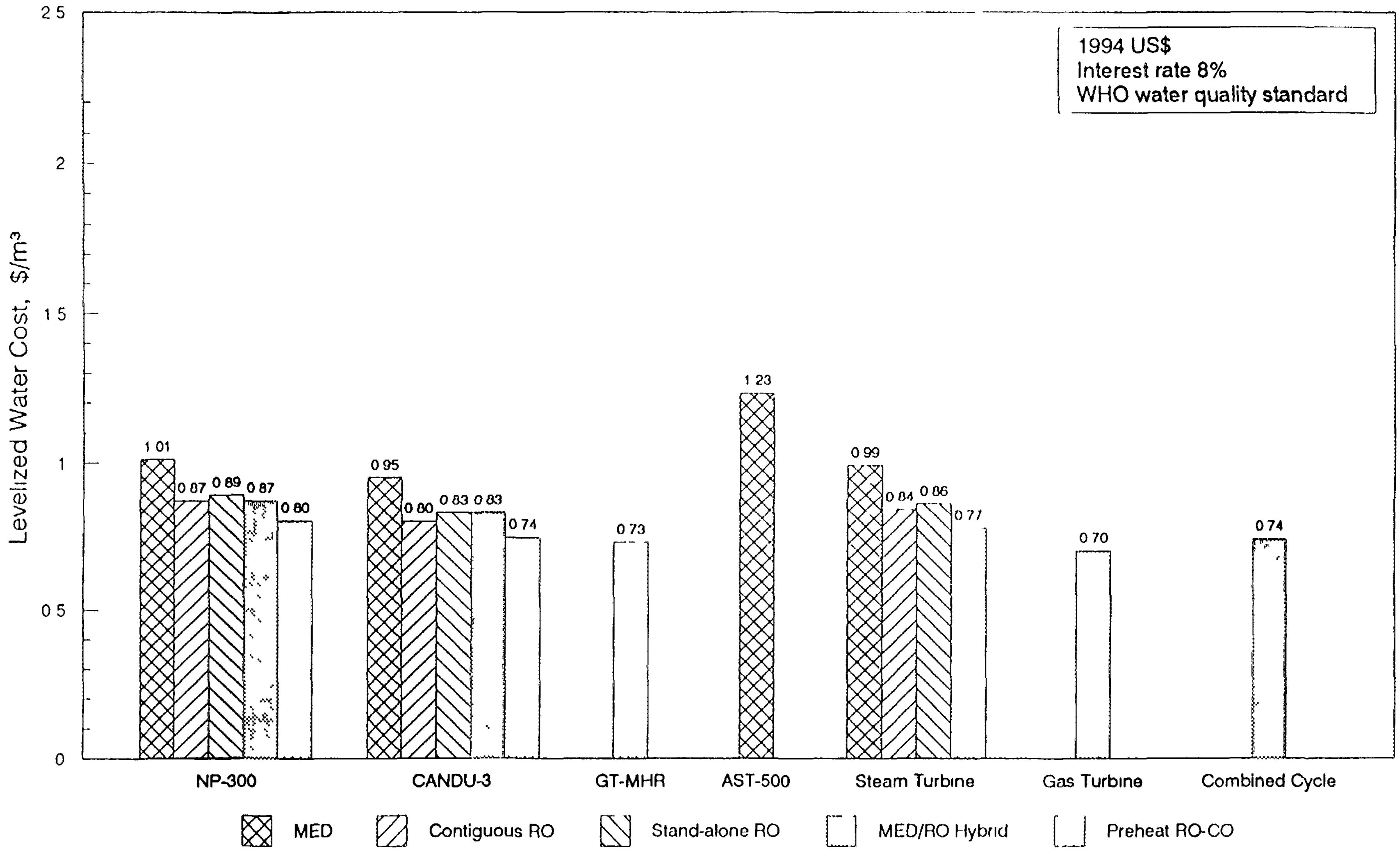


***Fig. 23:** Water costs of desalination plants, Regional study (Libya site: 720 000 m³/d)*

(Data given in this figure are only indicative)

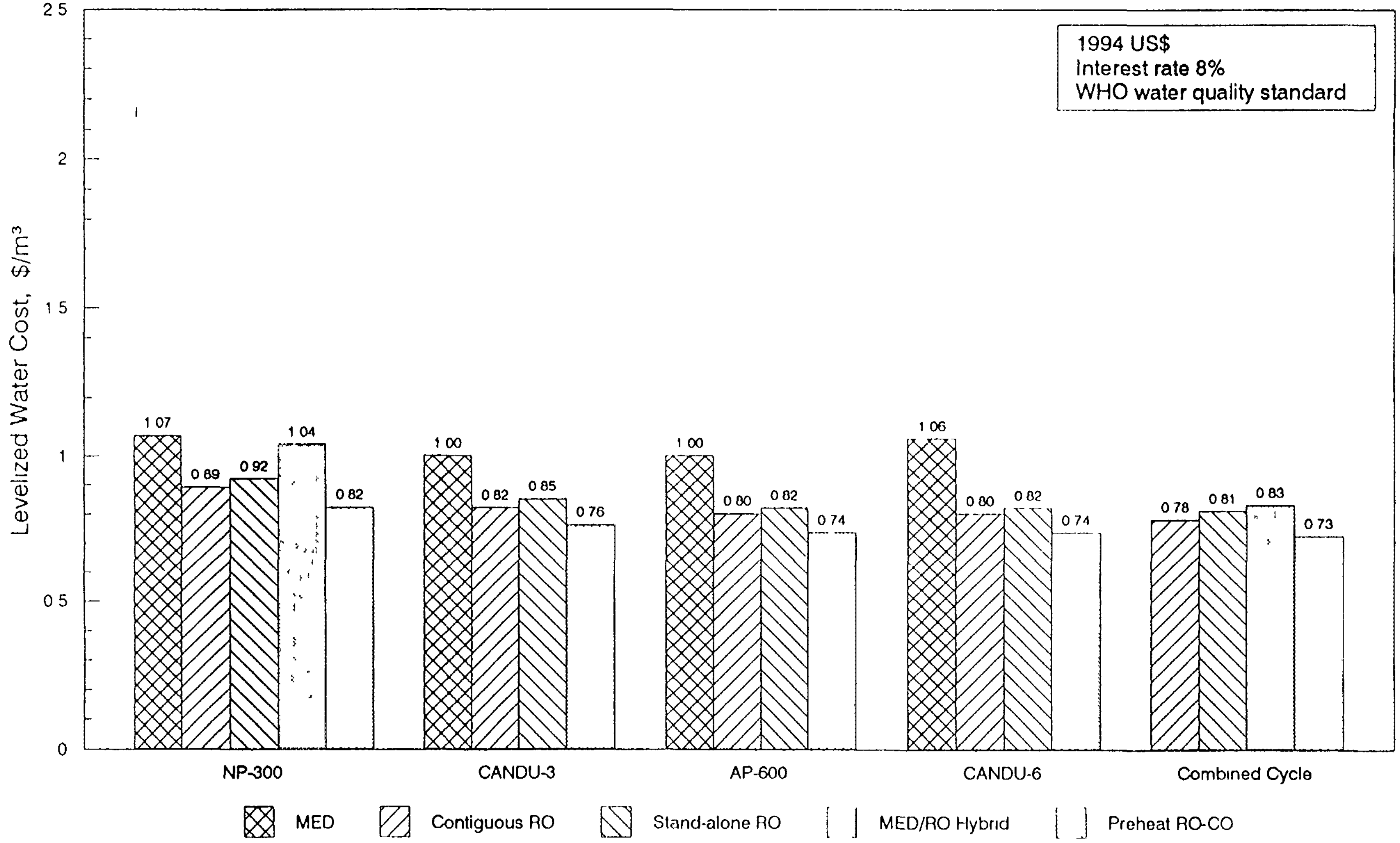


Fig. 24: Water costs of desalination plants, Regional study (Egypt site: 240 000 m³/d)

(Data given in this figure are only indicative)

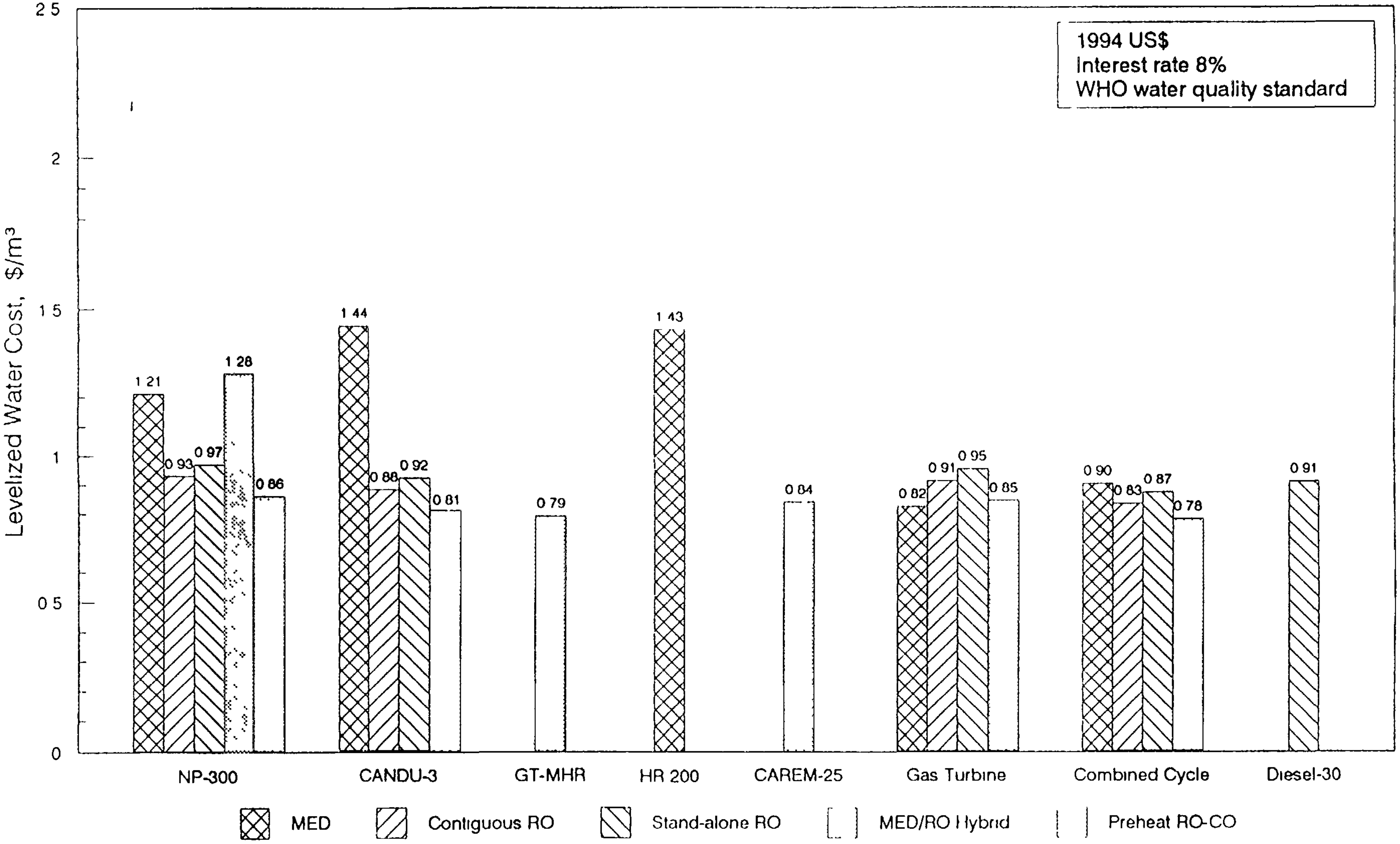


Fig. 25: Water costs of desalination plants, Regional study (Algeria site. 120 000 m³/d)

(Data given in this figure are only indicative)

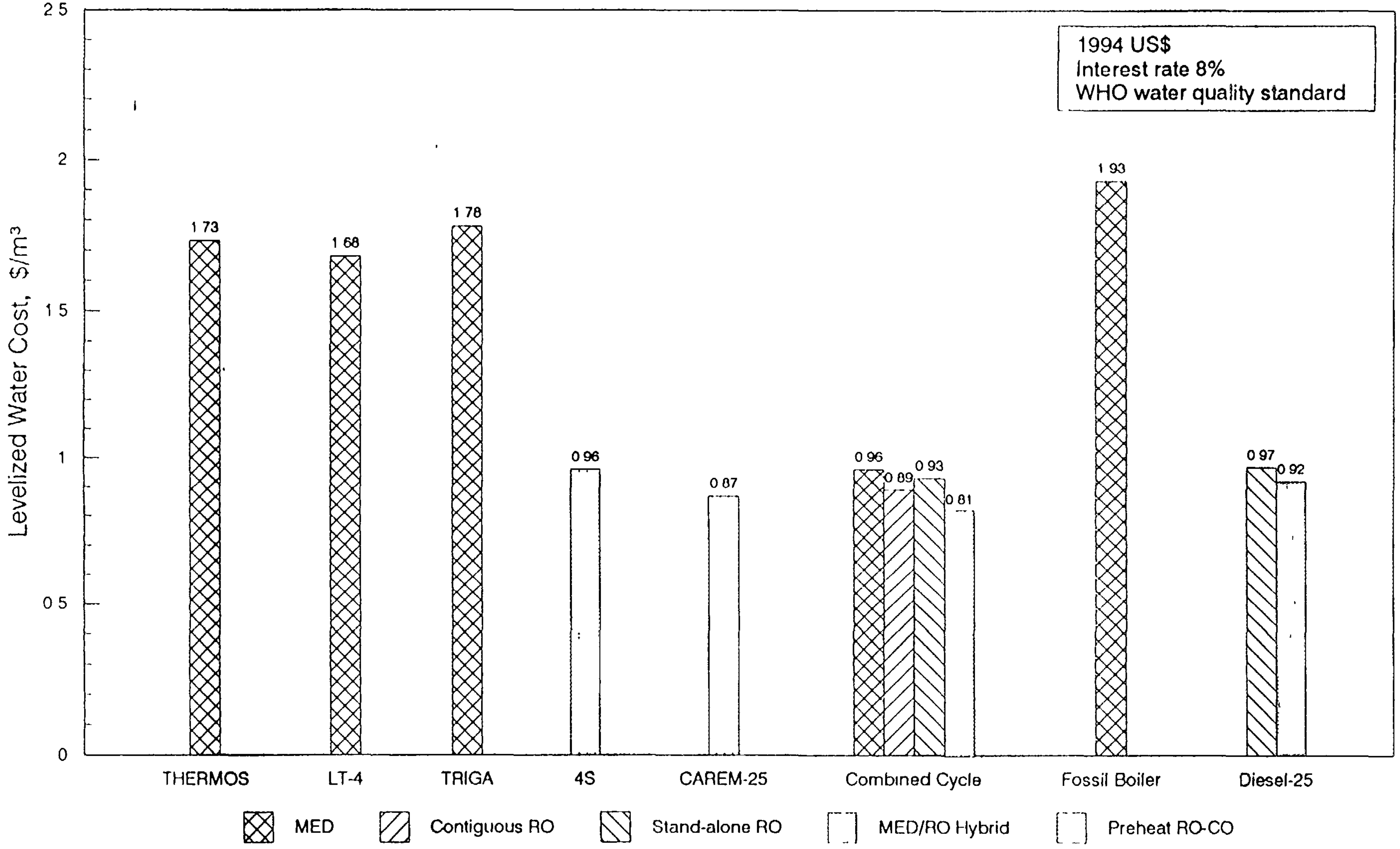


***Fig. 26:** Water costs of desalination plants, Regional study (Tunisia site: 60 000 m³/d)*

(Data given in this figure are only indicative)

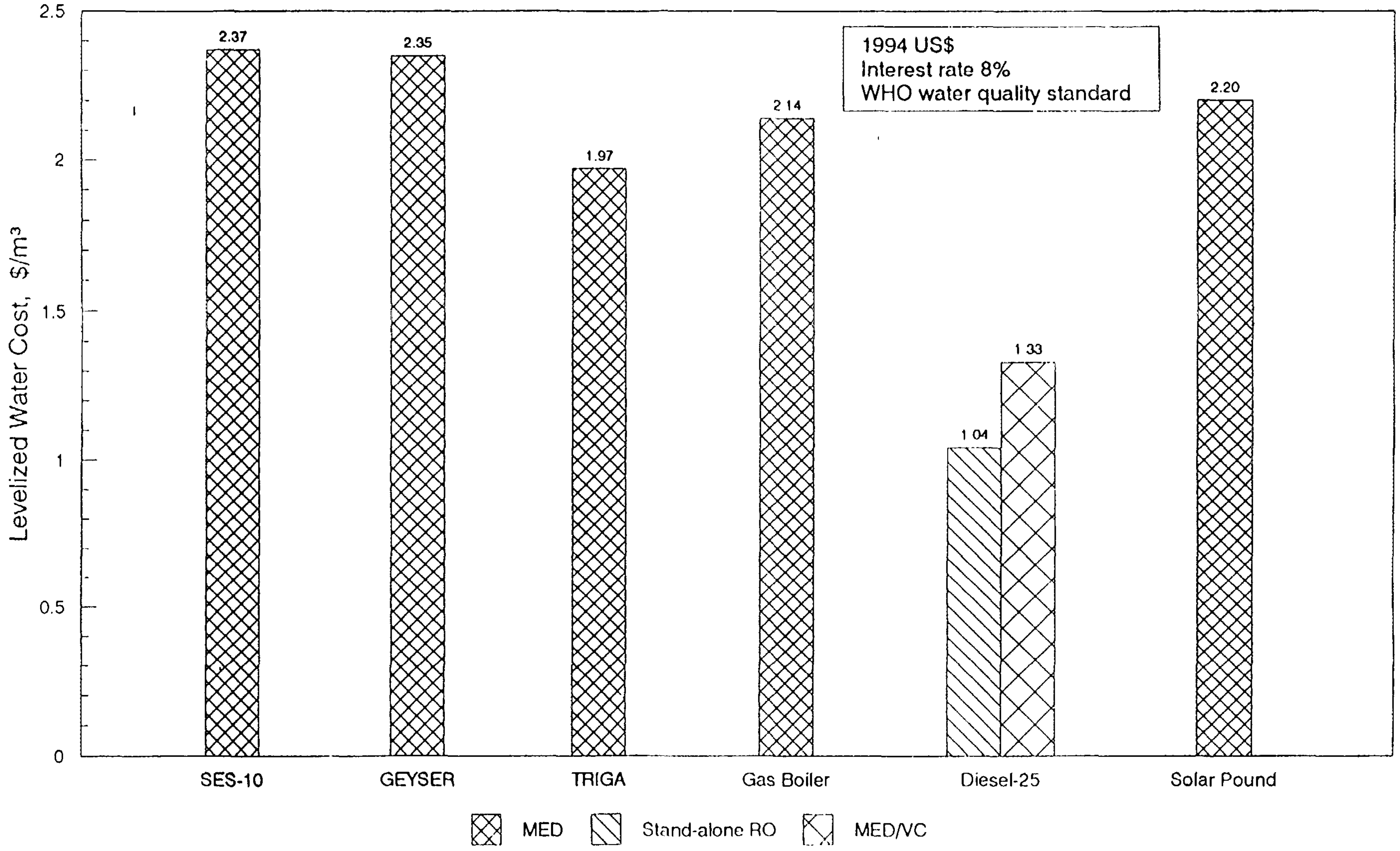


Fig. 27: *Water costs of desalination plants, Regional study (Morocco site: 24 000 m³/d)*

(Data given in this figure are only indicative)

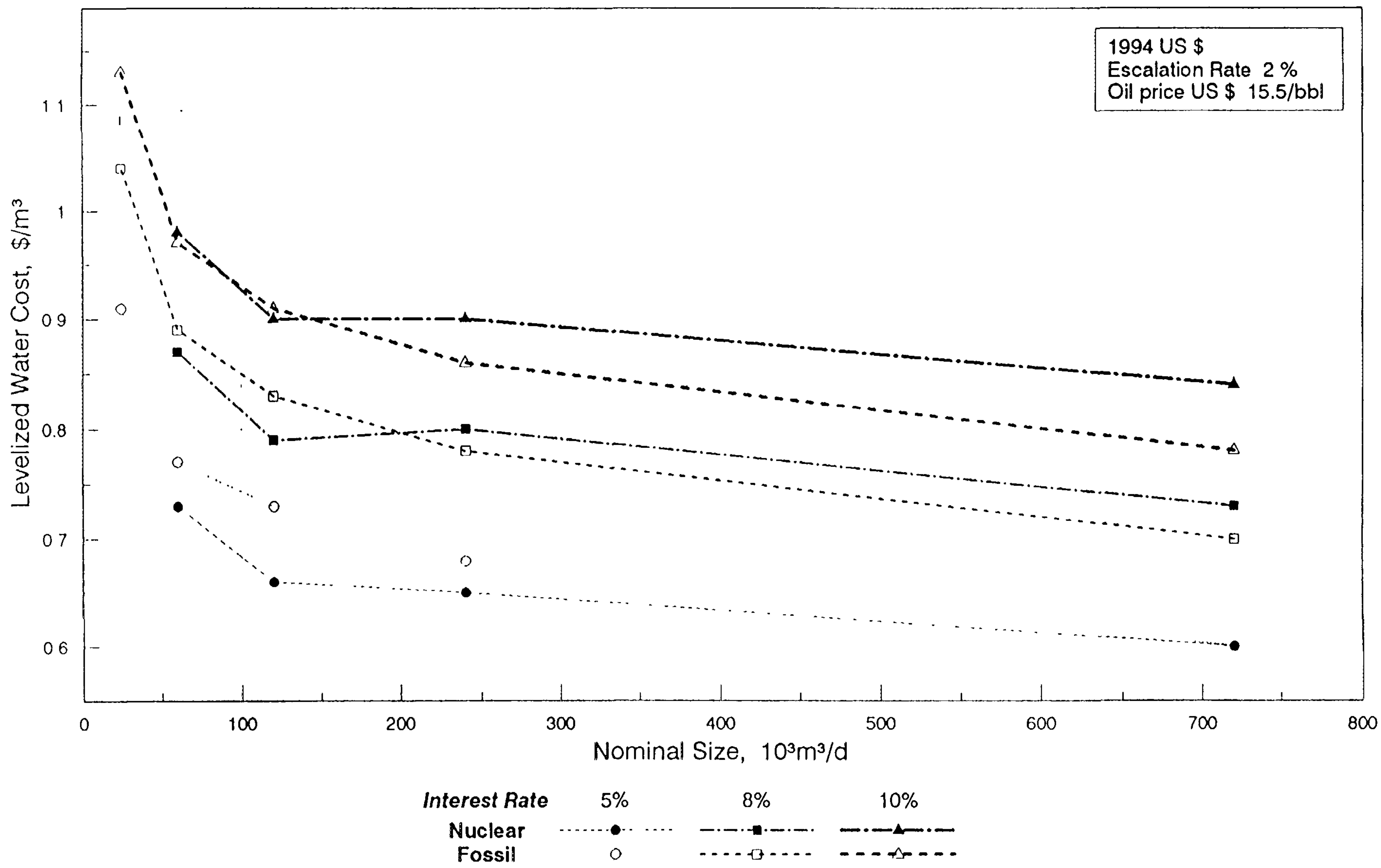


Fig. 28: Comparison between the most economic nuclear and fossil options for various interest rates

(Data given in this figure are only indicative)

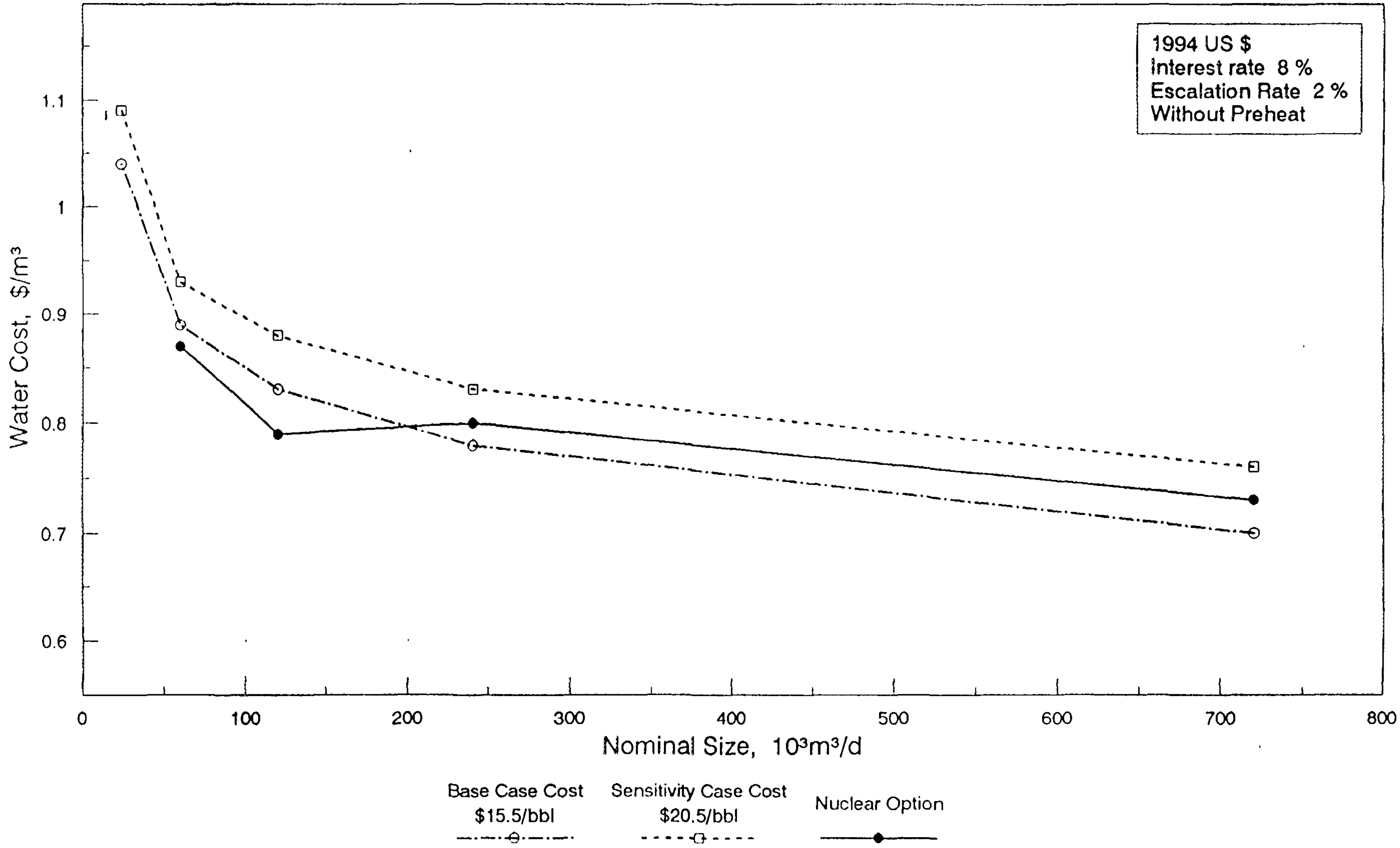


Fig. 29: *Comparison between the most economic nuclear and fossil options for various oil prices*

(Data given in this figure are only indicative)

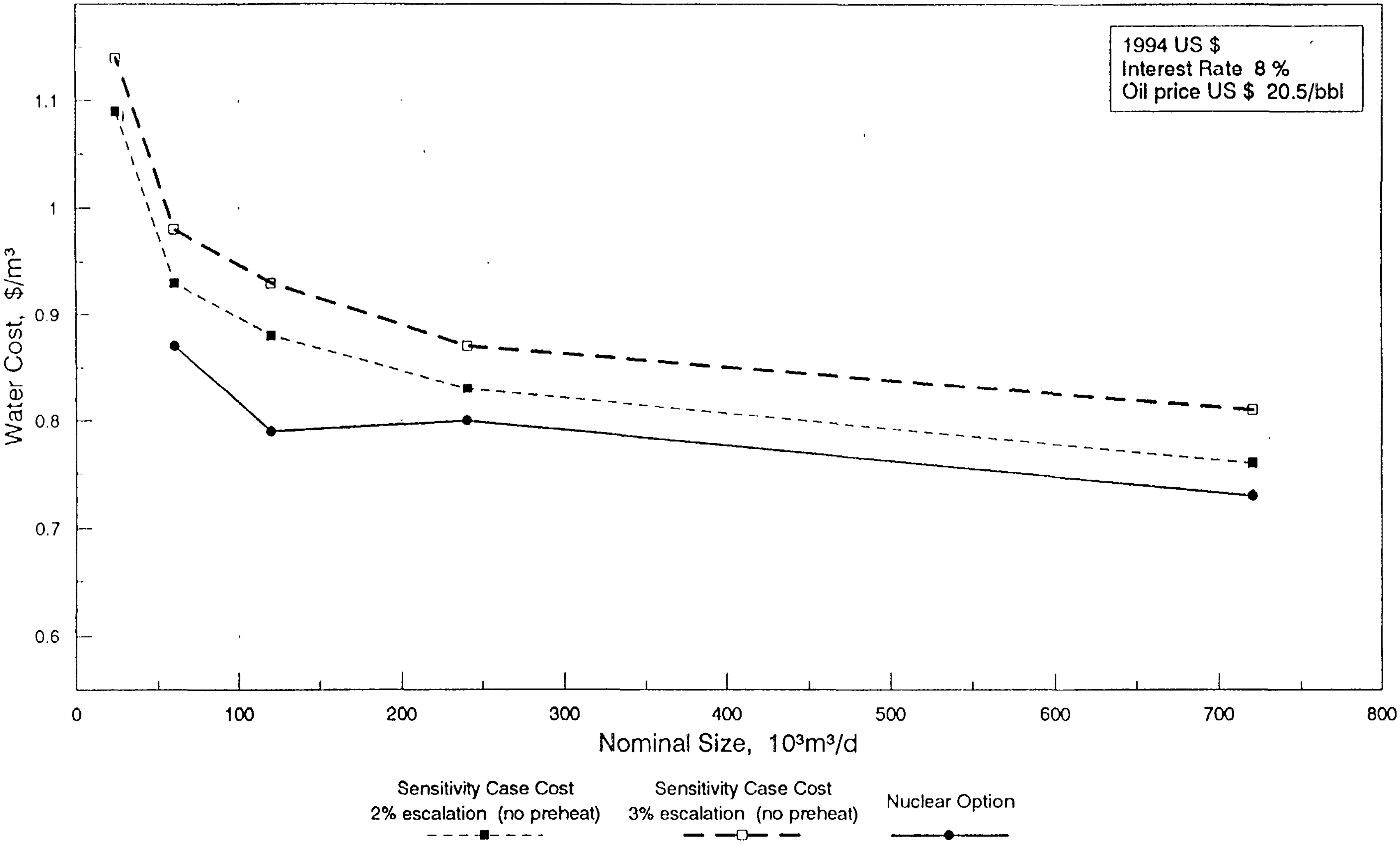


Fig. 30: Comparison between the most economic nuclear and fossil options for various escalation rates

(Data given in this figure are only indicative)

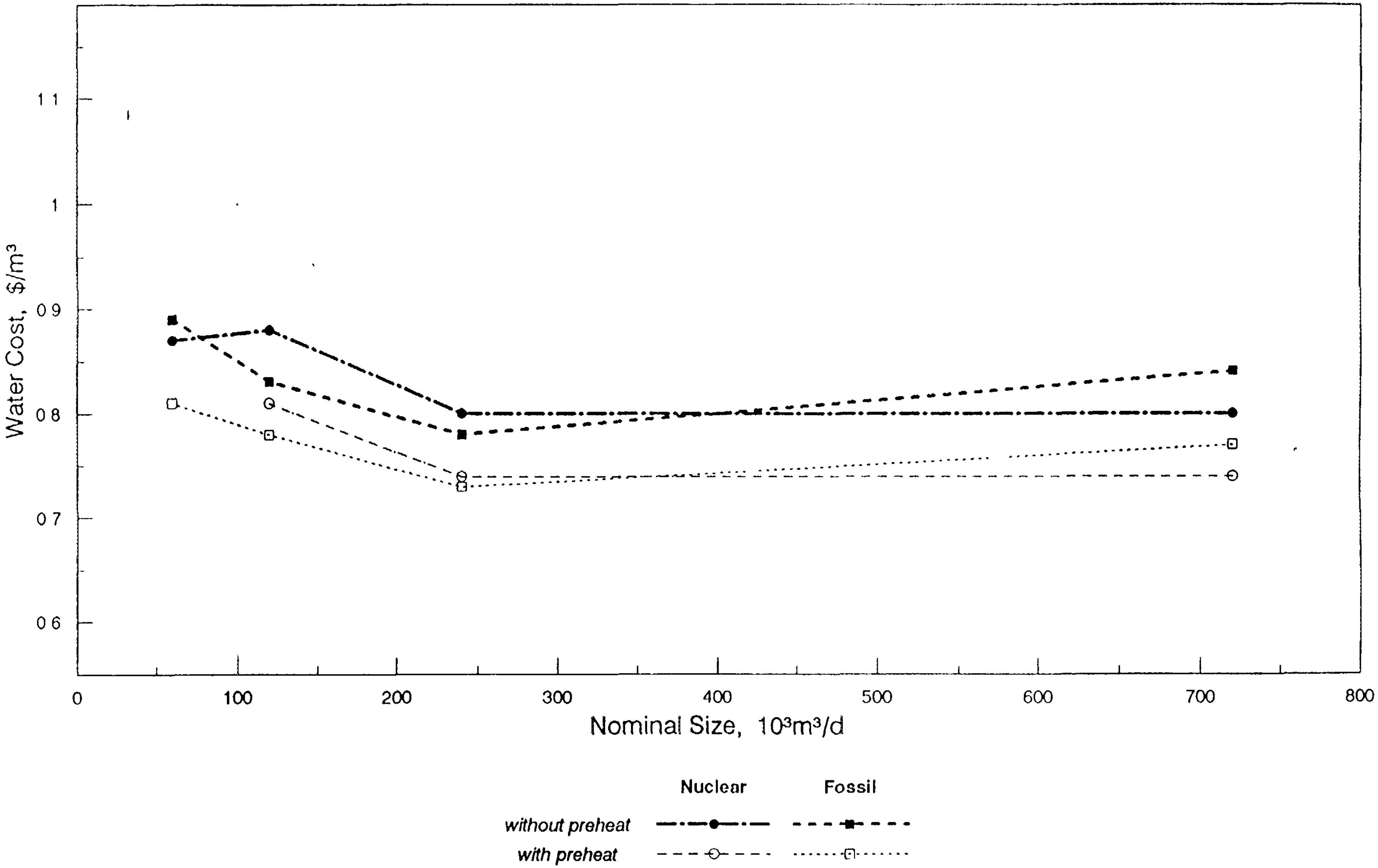


***Fig. 31:** Effect of preheat on selected nuclear and fossil options*

(Data given in this figure are only indicative)

11.6 UNCERTAINTIES AND SENSITIVITY ANALYSIS

Uncertainties in the utilization of advanced small and medium nuclear power plants for seawater desalination in the NACs appear to be quite large. With the single exception of the CANDU 6, none of the nuclear options or the desalination plants with the sizes considered in this study have been built anywhere in the world. Uncertainties of construction costs include:

- Impact of construction in the NACs (including impact of local participation)
- Schedule overrun.
- Escalation and general construction cost uncertainties.

Uncertainties exist also with plant reliability and availability of both the nuclear reactors and desalination plants. Although reactor suppliers and desalination consultants are confident that energy and water availability of 80% and 91% can be attained, this will largely depend on the qualification and discipline of the plant staff and the reliability and availability of management. The escalation rates of O&M costs and fuel price are also uncertain. This applies particularly for future oil prices. A limited sensitivity analysis was performed on some of the above mentioned parameters. In particular, interest rate, oil prices and the escalation rate of oil prices. The results of these analyses are shown in Figures 28 -30.

The sensitivity analysis of interest rate (Figure 28) indicates that while the base case (8% interest rate) would give similar range for both of the nuclear and fossil options, an interest rate of 5% will make the nuclear option more economic. For a 10% interest rate the fossil option is much cheaper.

An increase in the oil prices to US$ 20.5/bbl including transportation cost, and with the same 2% per year escalation rate, will render the nuclear option more economic (Figure 29). A limited sensitivity analysis was performed to show the effect of escalation in oil price for a base oil price of US$ 20.5/bbl (Figure 30). The results indicate that higher escalation rates tend to favor the nuclear option.

It was clear from the discussion of the results, that contiguous RO appears to be the most economic desalination process. This arrangement gives the opportunity for utilizing the condenser for preheating the feedwater to the RO system. This was already done for GT-MHR/RO-C and CAREM-25/RO-C. To examine the effect of pre-heat, limited calculations were performed for CANDU-3/RO-C in the Algerian and Libyan sites as well as the CANDU-6/RO-C in Egypt. The results are included in Table 84 and are shown in Figure 31, and indicate that the utilization of contiguous RO systems with preheat can reduce the water cost considerably.

11.7 CONCLUSIONS FROM THE ECONOMIC EVALUATION

The results of the economic evaluation cover a considerable range. Under the assumptions and coupling schemes utilized in the evaluation, the levelized water costs for both of the nuclear and fossil options were in the same range. Higher oil prices and/or lower interest rates favours the nuclear options. The most economic desalination process appears to be contiguous RO with preheat.

Early introduction of nuclear energy for electricity generation and/or for seawater desalination will extend the life of the depletable fossil fuel resources in the Region. However, the economic feasibility of nuclear desalination in the NACs depends strongly on the cost at which the nuclear reactors can be constructed. To obtain a firmer basis for conclusion, it will be important to reduce the range of uncertainty. A preliminary conclusion on the competitiveness and viability of nuclear desalination can be reached at the feasibility study stage. The final decisions on the investment could only be reached on the basis of response to an invitation to tender.

12. PROJECT FINANCING

12.1 GENERAL

Even with overall economic competitiveness and technological feasibility of nuclear power, the high capital requirements for nuclear power plants pose difficult financing problems, and financing remains one of the major constraints on nuclear power programs in NACs, and indeed in most developing countries.

When a nuclear power project appears to be economically feasible, a financial analysis has to be carried out in current money terms. Such an analysis will include general factors such as the design and construction period, current and projected escalation rates, current and projected currency exchange rate, fees (management fee, commitment fee, guarantee fee) rate of interest, grace period and repayment period. A financial analysis is essential because it can lead to conclusions quite different from those based solely on economic analysis.

In view of the general nature of the present feasibility study, it is not the objective of this chapter to provide a financial analysis of the nuclear desalination plants presented in Chapter 11, as the economic situation and financial constraints will differ from country to country and from project to project. Rather the objective is to emphasize the difficulties in financing electricity and water projects, stress the need for alternative schemes and discuss some of the proposed alternatives. This will be done based on related IAEA publications [86 - 89].

12.2 SURVEY OF REGIONAL EXPERIENCE IN FINANCING WATER AND ELECTRICITY PROJECTS

The bulk of the NACs sources of foreign currency have traditionally come from their primary exports such as: oil (Algeria, Egypt and Libya), natural gas (Algeria), phosphate (Morocco), and cotton textiles (Egypt). Other sources include: remittances from nationals working abroad (all except Libya), the Suez Canal fees (Egypt), tourism (Egypt, Morocco and Tunisia) and foreign grants and borrowing (all).

Economic trends indicate that most of the NACs suffer from deficits in the balance of payments and government fiscal operations, as well as heavy foreign debts. The situation regarding the national debt of different NACs, though improving, remains serious. While some countries have rescheduled their debts (e.g. Algeria and Egypt) and are paying the interest on step-by-step bases, the net export of goods is often still too low to supply sufficient foreign exchange for debt repayment.

Almost all power and water developments in the NACs were financed through government-owned utilities. Because of the uneconomic pricing of the products, often dictated by the governments as part of their subsidy policies, many of these utilities do not generate enough revenue for their operating and capital expansion purposes. In many utilities, the tariffs do not even cover the operating costs and debt service commitments. Therefore, water and electricity utilities often do not qualify for loans from international development or commercial banks. As a result they have had to depend on provision of funds by governments for new plant construction.

Many NACs governments have provided funds for power and water sectors either as allocations from their budget or by direct borrowing on behalf of utilities. Budget allocations have been provided as grants which were not repayable. In case of direct borrowing, funds have been lent by the governments to the utilities mostly on the same terms or in some cases at lower rates.

Most of the NACs took some corrective actions towards implementation of economic stabilization and structural adjustment. An important step in this direction was minimization or abolition of subsidies in all forms. For example, the stated policy of the Egyptian Government is to remove fuel oil subsidies for power plants, to achieve the goal of alignment with world fuel prices by 1995 [82].

The internal cash generation of an enterprise is the revenue remaining after meeting operating costs (before depreciation) and debt service, i.e. interest and principal payments on debt capital needs. Ideally, this should be the most important source of finance for power and/or water development, however, internal funds for construction are usually non existent in third world countries. A recent study by the world bank that included three of the NACs power companies indicated that only 5% of needs were financed during the 1980s from internal sources as shown in Table 86.

TABLE 86: SOURCES OF FUNDS IN NORTH AFRICAN COUNTRIES AS A PERCENTAGE OF CAPITAL EXPENDITURE (FY 1979-1988)

Country/Utility	Internal	Borrowing	Equity	Capital Contributions by the Owners
Algeria/ Sonelgaz	- 2.8	66.6	22.9	13.2
Egypt/EEA	-	-	-	-
Libya/GEA	-	-	-	-
Morocco/ONE	- 2.3	60.0	25.3	17.1
Tunisia/STEG	20.8	49.2	11.2	18.9
Average	5.2	58.6	19.8	16.4

* Source World Bank (Based on local currencies at 1987 constant prices)

12.3 PRIMARY CHARACTERISTICS OF NUCLEAR POWER PROJECTS

There are four primary characteristics specific to nuclear power projects, as follows [86], which make the arranging of adequate financing even more difficult.

12.3.1 Capital Intensity

Depending on the plant size, construction time, financing terms, interest rates and other factors, costs have ranged from US$ 1,000 - US$ 3,300 per installed kW(e). This large capital requirement may approach or even exceed the overall available credit limits identified by lenders for an individual developing country. Also, lenders may be reluctant to concentrate their financial risk in a single project of this magnitude.

12.3.2 Long Construction Time

Construction periods for nuclear power plants in various countries have ranged from 4 to 15 years. A good average projection of construction time would be about eight years. During this long construction period, and because of it, the owner is confronted with interrelated problems which are more severe for nuclear power projects than for other kinds of projects. These are:

- Lack of revenue from the project, as the plant under construction is not yet producing.
- The financial requirement to pay interest during construction.

Clearly, any delay in bringing the project on-line will have major implications for its economic feasibility.

12.3.3 Uncertainty Regarding Costs and Schedules

Experience in various countries has shown that a nuclear project can face many uncertainties which can lead to construction times being longer than expected and, as a consequence, to large cost overruns. Delays arise for various reasons, for example, regulatory intervention, inadequate local financing and unexpected site conditions. Unpredictable additional costs due to escalation can also be a problem.

12.3.4 Public Acceptance

In addition to the cost related considerations mentioned above, public acceptance of nuclear power has become an important issue for the general public, professionals and decision makers. Since the Chernobyl accident, heightened public concern with nuclear risks has had a direct and profound influence on nuclear power projects including costs worldwide.

12.4 ISSUES AFFECTING PROJECT FINANCING

An IAEA senior expert group [87] specifically identified the main issues affecting the financing of nuclear power projects and suggested action that each party involved (lenders, export credit agencies, suppliers, investors, multilateral organizations and developing countries) could take, to reduce the economic and financial risks and to make a nuclear power projects more predictable. These issues are grouped into five major areas: programme and projects related factors, the investment climate, financing plan, export credits and credit worthiness.

12.5 IMPORTANCE OF LOCAL FINANCING

If funding from the national budget or a sponsor's equity and cash flow were adequate to implement a project, there would be no problem in financing. If a country launching or expanding a nuclear power programme is creditworthy, it can obtain export credits and procure funds by international borrowing. If the capital market is relatively well developed in the host country, local financing may be easier. The reality, however, has proven to be different.

One of the most difficult problems to be faced with regard to financing nuclear power projects in developing countries is arranging the finance to cover local costs, whose complexity is often underestimated. Experience shows that raising enough money for local costs financing from foreign sources, local capital markets or government budgets has often proved to be impossible and has been the main reason for delays in project implementation, at least after the initial and more technical problems of the projects have been solved.

Covering the gap in financing local costs by using foreign exchange funding from abroad often proved to be problematic. To avoid straining the foreign exchange balance of a country, with all the associated negative impacts, local costs should in principle be financed in local currency from sources within the host country itself (from the buyer's revenues from other projects, from the national budget or from funds raised in the domestic capital market). This is especially necessary as power plants are almost always operated for domestic use only, thus generating cash flow only in local currency.

Sound sources of local currency funding for investment in a public utility power project would be the government budget and the funds of the projects of operating organization/utility, either from equity or from accumulated earnings set aside especially for such a planned investment. These sources could be supplemented by credits raised in the domestic capital market. Difficulties in financing local costs arise from shortages of government funds and constraints in local capital markets. The development of well functioning domestic capital markets is particularly important for organizing local financing. As foreign currency financing of local costs increases the debt burden and carries a foreign exchange risk, it is vital for successful project implementation to secure sufficient local financing.

As much as possible of the total project costs, but in any event the local portion of these costs, should be financed with domestic funds. Adequate local financing must be arranged in good time and, in the case of loans, for a reasonable credit period. Local financing should be secured in advance either through binding agreements or, for instance, by accumulating adequate funds similar to escrow accounts, prohibiting the use of these funds for any other purpose. In this context, the importance of fixing reasonable electricity tariffs by the government concerned must be emphasized, for only in this way will the project executing agency achieve the sound financial strength needed to finance investments from its own resources or be considered creditworthy by banks.

12.6 REVIEW OF FINANCING SCHEMES

Power sector projects require for their realization both a financing component in national currency, for the part of investment activities to be paid for locally, and a financing component in foreign currency, for payment abroad for imported goods and services. Available financing sources for power generation systems in developing countries have been utilized for:

- Covering domestic investment using the utilities' own resources, to the extent that these are insufficient, the government budget. In a limited number of cases, the capital market in the countries concerned have generated resources to cover, or to contribute to, the domestic financing requirements.
- Covering capital requirements in foreign exchange. Supplier's credit or financing arrangements through commercial banks guaranteed by export credit agencies have been used widely. Credits from multilateral bilateral sources have become increasingly important.

It is expected that the major difficulties which developing countries, including the NACs, will encounter in financing power sector development, will be related to the internal part of investment, owing to: low domestic savings rate, limited capabilities of the utilities internal cash flow generation, inadequate tariff system, low capacity utilization and slow collection of bills by the utilities, and the absence of domestic long term capital markets in developing countries. Investment financing requirèments which cannot be met by domestic sources have to be drawn from international financing sources.

If the host country faces a creditworthiness problem, financing a nuclear power project is a very difficult, if not impossible, task. It is then necessary to consider additional innovative approaches beyond those which are currently being used. The balance of this section reviews both current and alternative approaches for mobilizing financial resources.

12.6.1 CURRENT APPROACHES FOR FINANCING LARGE PROJECTS

12.6.1.1 Local Financing Sources

The sources of national or local financing are [86]:

- Investor's own resources:
  - Equity capital.
  - Cash flow.

- Debt Capital:
  - Domestic bonds.
  - Local bank credits.
  - Donations and Credits from public entities.
  - Stand-by facilities for cost increases.
  - Prepayment for future services of the project.

Shortfalls in local cost financing have led some governments to create new sources of medium to long term local financing, as well as to increase contributions from the public budget for financing the projects and to make direct equity injections to the national power utilities. One relevant example is the Alternative Energy Fund of Egypt [82, 88, 89], which is described in Section 12.7.

12.6.1.2 International Financing Sources

Examples of international sources and the relevant insurance agencies for power sector investment projects in developing countries are listed and discussed below.

i) Export credits, which include:

- Export Credit Agencies (ECAs);
- Equipment Supplier's credit.

Export finance through ECAs has been playing a significant and growing role in financing energy projects in developing countries. In general, two types of lending programmes are available from ECAs to finance electric power projects in developing countries. The first is a supplier's credit, by which ECAs extend credits to their countries' exports. The other scheme is a buyers credit, in which an ECA directly funds overseas buyers or overseas financial institutions. The terms of the above types of export financing are bound by OECD Consensus on export credit. Under the Consensus arrangement, the use of tied aid credits, associated financing, aid loans and grants for the supply of nuclear power plants are in any case prohibited.

ii) Bilateral Financing Sources

For example, member countries of the development assistance committee (DAC) of the OECD. However, because of the OECD Consensus, financing of nuclear power projects in developing countries, is not permitted.

iii) Multilateral Development Institutions, which include:

a) The World Bank Group, consisting of:

- The International Bank for Reconstruction and Development (IBRD).
- The International Development Association (IDA).
- The International Finance Corporation (IFC).
- The Multilateral Investment Guarantee Agency (MIGA).

b) Regional Development Banks and Organizations such as:

- The African Development Bank (AFDB).
- The African Development Fund (AFDF).

c) Other Institutions, including:

- The Islamic Development Bank (ISDB).
- The Arab Fund for Economic and Social Development.
- The Saudi Fund for Development.
- The Kuwait Fund for Development.

The stated common objectives of the World Bank Group is to help raise standards of living in developing countries by channeling financial resources from developed countries to the developing world. In 1974, the Bank reached the conclusion that, technically and economically, nuclear power projects could be dealt with using its normal procedures. However, no such funding has as yet taken place. The World Bank seems, in practice, to take the position that as a financier of last resort, it is unnecessary for its fund to be allocated for nuclear power projects.

The regional banks and other institutions, listed in b) and c) above, are potential sources of financing, particularly for the NACs who are members of the Islamic, Arabic and African organizations. These banks have the advantage of proximity to and close knit relations with their member states and detailed knowledge of local conditions, resources, priorities and needs to the power and water sectors.

Based on current trends, it seems that the future additional funds will come mainly from international capital markets, which have been expanding rapidly. NACs should make every effort to become and remain reliable borrowers on the international capital markets, both by careful study of the lenders' loan conditions and by developing in their countries or regionally the managerial framework and expertise to put these loans to the best use and service them punctually.

12.6.2 Alternative Financing Approaches

In view of the increasing need for foreign exchange in most developing countries and the difficult situation of the present international financing environment as regards meeting the financing requirements of a nuclear power project in a developing country, additional approaches and complementary mechanisms are being sought. These include: non-recourse or limited recourse financing techniques for mobilizing additional external finance resources for power development, the World Bank's partial guarantee approach and other ideas [89].

To date, no large power project in any country has been implemented using these new approaches. However, some countries are now involved in a long process of negotiating innovative financing approaches for their power sector development. Such approaches include:

- Build-Operate-Transfer (BOT).
- Expanded Co-Financing Operations (ECOs).
- Countertrade Arrangements.
- "Whole-to-Coal" model.

The above approaches are briefly described below.

12.6.2.1 BOT Approach

The basic framework of a BOT approach is as follows [89]. As number of foreign investors form a consortium, the consortium establishes a joint venture company (JVC) with a local utility, and this JVC sells the electricity generated to the utility. These foreign investors procure most of the funds for the project, which are used to:

- build a power plant with foreign engineering expertise;
- have the plant to be operated managerially by foreign investors/operators for a certain period until all costs, debt service and equity are recovered by means of an electricity tariff;
- transfer the ownership of the plant to the country in which it is built.

A variant of BOT is the BOO (Build-Own-Operate) approach, which does not involve transferring the plant to the host country. A BOO plant can, in principle, continue in private hands throughout the useful life of the project or to some earlier date agreed on by the host government and the private owner.

When a power plant is implemented under a BOT approach in developing countries, the following advantages may generally be expected:

- Attraction of foreign capital in the form of non-government debt for power plants.
- Reduction of the risks related to construction and operation under the consortium's expertise and experience.
- Provision of practical opportunities for training and technology transfer during the course of construction and operation.

However, it should be noted that there are a number of serious arguments against the BOT approach. BOT projects are immensely complicated and time consuming undertakings from both a legal and a financial point of view, and the overall costs for a BOT project would be higher than for a project financed directly by sovereign borrowings.

12.6.2.2 ECOs Approach

The World Bank has recently developed a new co-financing programme, ECOs, which are intended to promote increased financial flows by providing enhanced coverage of risks that would not otherwise be assumed by private lenders. ECOs are to be made available for specific projects or investment programmes that are identified and appraised by the World Bank, and that are normally accompanied by World Bank loans [89].

The first project under this new co-financing approach would be in Pakistan, the Hub Power Project, which is under negotiations and proposes a BOO approach. The World Bank's guarantee of the host government's obligations to support the project and the World Bank's policy guidance or other measures involving the host government would tend to diminish political risks, thus reducing the risks assumed by the sponsor and participating lenders. The ECOs approach could be effectively applied to support privatization programmes to be undertaken in many developing countries in the future.

12.6.2.3 Countertrade Arrangements

For countertrade or barter arrangements, the financing and supplying sources are expected to come from the same country. Such arrangements can easily be applied in cases where the products have an external market and can be sold outside the host country. However, electricity is not usually such a product; and therefore other products or services have to be marketed by the suppliers. The problems with countertrade arrangements concern [89]:

- The kinds of commodities or services the host country can provide.
- The kinds of commodities or services the supplier country can accept.
- Setting the prices of such commodities or services.
- Balancing price against quantity to be supplied, especially in the case of low price products from light industry or agriculture.

The supplier country will have to bear the market and price risks of the received products and must very often involve professional companies for this purpose, which results in additional expenses. If the host country has existing commodity exchange arrangements with the supplier countries, a countertrade arrangement could be utilized. In practice, financing plans involving countertrade appear to be complicated and economically unfavourable compared with other conventional financing approaches and could probably contribute to providing only a part of the foreign currency requirements.

12.6.2.4 Whole-to-Coal Model

The "Whole-to-Coal" concept is one in which the purchasing utility and its customers are assured of the same economic and financial situation as would be the case if the utility had constructed a coal plant rather than a nuclear unit [89]. The nuclear unit would be owned by a supplier entity. During the construction and early operating period, the utility's financing requirements would be equal to the coal alternative. Buy-out would be mandatory (subject to plant acceptability and performance tests) at a pre-agreed time. On an agreed schedule, the utility would pay back all earlier amounts of financing from the supplier entity, including any losses from selling power on a coal basis, together with interest. This model is being used in negotiations between a Canadian utility and the supplier of a 450 MW(e) CANDU-3 unit.

Viewed from the perspective of a small utility, the advantages of this model are:

- It limits the initial capital investment and early power generating costs for the buying utility to the level of an equivalent coal plant.
- It spreads the financing requirements over a much longer time, thereby making a nuclear unit financially more feasible.
- The nuclear unit has a demonstrated track record before the buyer raises the bulk of the financing.

12.6.2.5 Concluding Remarks

Since the application of these alternative approaches for nuclear power projects in developing countries is more complex and risky than for conventional power projects, investors, host governments and financial institutions will be looking very closely at the track record for developing and implementing these new approaches. This scrutiny will encompass a review of all phases of existing projects, including final settlement of financing arrangements and plant completion/operations, before, these parties will pursue new approaches for a nuclear power project in a developing country.

In particular, the outcome of the Turkish coal fired power project and the Hub Power Project in Pakistan will no doubt influence that attitude of investors to the BOT or BOO options for large size projects. The BOT/BOO approaches for nuclear power projects in developing countries by no means provide a panacea. They are possible but untested alternatives for revenue earning power projects, particularly for complex nuclear power projects. The results of negotiations on the projects in Turkey and Pakistan could, but may not necessarily, give an indication of the potential for these approaches to be applied to nuclear power projects in developing countries.

12.7 POSSIBLE ALTERNATIVES PROPOSED FOR THE NACs

It is clear from the above discussion that providing the foreign component of investment for nuclear power projects in the NACs from international markets could be problematic. Therefore, NACs will have to depend on their own resources either individually or collectively.

A relevant individual or national solution is the Alternative Energy Fund of Egypt. The Egyptian Government decided to allocate a portion of its oil revenue surplus to cover part of the foreign component requirements of oil alternative energy projects. This oil revenue surplus is placed in a special fund that is not intended to cover the local currency content, but meant to cover, to tent possible, the foreign currency requirements of oil alternative energy projects. At the time of creation of the fund, Egypt intended to build eight nuclear power plants up to the year 2000. About US$ 1125 million is already available in this fund [82, 89].

A collective or regional solution could be the establishment of a Regional Drought Fund. The idea, which was proposed by Libya during the course of the present study, suggests the establishment of fund in an international institution such as the World Bank, to finance water development projects including nuclear desalination in the five NACs. The fund is not to be used for straight forward commercial projects. The NACs contribution to the fund would be based on GNP of the respective country. However, the details of this proposal should be worked out. Probably, joint venture utilities should also be established to operate water projects to the benefit of all countries contributing to the fund.

To minimize the burden of the foreign investment costs to construct nuclear power plants, NACs should also aim at:

- Maximizing the regional manpower participation in all stages of the project.
- Maximizing the regional participation in manufacturing the components of the plant.
- Self-dependence for spare parts and consumables to the maximum possible extent.
- Construction of SMPRs with the objective of reducing the amount of direct and indirect investments which would be required for larger nuclear power plants.

13. JOINT REGIONAL ACTIVITIES

13.1 GENERAL

One of the important characteristics of the post World War II era is the tendency of individual states, developed or developing, to agglomerate in larger entities for political, economical or cultural reasons, in order to optimize the utilization of their resources and protect their common interests. The European Economic Community is an example of such a regional co-operation.

The North African Countries share a common land without any natural barriers as well as common language, culture and national feelings. All the NACs are active members of the Arab League, the main organ for co-ordination between the Arab Countries. They are also members of other Regional and Cultural organizations, namely the Organization of African Unity and the Organization of Islamic States. Therefore, links already exist to support co-operation activities.

The present level of co-operation between the Arab Countries in general, and the NACs in particular is indicated by the inter-trade figures shown in Tables 87 and 88. It is clear from the Tables that the inter-trade in North Africa is even lower than that of the Arab Countries as a whole. However, there is room for improving the level of regional co-operation between the NACs. The balance of this Chapter discusses the advantages of Regional co-operation, possible areas for Regional co-operation, and proposes some regional projects.

13.2 ADVANTAGES OF REGIONAL CO-OPERATION

All NACs are developing countries, therefore, they suffer, to various degrees, from inadequate infrastructures and services, limited internal market and difficulties in international market, as well as, deficit in their balance of payment and heavy foreign debts. Regional co-operation, particularly in satisfying their needs for electricity and water, include but are not limited to the following advantages:

- Reduction and possibly elimination of short and medium term needs for installation of new power plants through unification of their national power systems. This will allow the utilization of the existing reserves in each NAC due to the difference in peak loading among the countries.
- Standardization of power plants will facilitate local participation and manufacture on the country and regional levels, as well as enlarging the market for local industry, hence, improving the feasibility of local manufacturing. This will lead to minimization of foreign currency components in future projects.
- A more efficient utilization of the NACs limited highly qualified and skilled manpower, as well as minimizing the cost of developing further manpower capabilities.

TABLE 87: SHARE OF INTERNAL EXPORTS IN SOME REGIONAL GROUPS IN 1989

Region	Share of Internal to Total Exports
European Economic Community	59.8%
North America Free Trade Area (NAFTA)	23.8%
Arab World	8.0%
North Africa (Algeria, Libya, Mauritania, Morocco and Tunis)	2.3%

* Source Reference [90]

The present Regional Feasibility Study constitutes a clear example of regional co-operation among the NACs, and a promising start to further promote the sharing of efforts and ultimately also the benefits. Lessons have been learned. It has been found that there are problems and difficulties in co-ordination, communications, control, the assignment of responsibilities, and the performance of tasks on schedule. There are also differences among the NACs regarding resources, capabilities, requirements and interests. Nevertheless, it has also been found that there are ways to solve the problems and it is possible to reach workable compromises.

The above lessons can be applied in the future, when joint co-operative efforts are undertaken within the Region to the mutual benefit of the participating countries, directed towards the development of local infrastructure, as well as specific seawater desalination projects combined with nuclear plants.

The field of seawater desalination through utilization of nuclear energy is new to all countries of the Region, therefore a new, co-operative approach might possibly be applied easier than in other fields where practices are already established, and where a change of attitude would be required. The main areas where regional co-operation appears to be of special interest are discussed in the following sections.

13.3 AREAS OF REGIONAL CO-OPERATION

Regional co-operation in the field of nuclear desalination should be viewed as a part of a wider regional co-operation in the fields of energy, water and industry.

Co-operation in the energy field includes long term regional energy planning, unified regional power system, proper energy mix e.g. conventional, nuclear and renewable. Co-operation in the water field includes items such as: long term regional water policy, water management, utilization of common aquifers, modernization of irrigation techniques, changing crop structure and joint desalination plants.

TABLE 88: COMMERCIAL EXCHANGES BETWEEN THE NORTH AFRICAN COUNTRIES (YEAR 1989) - IN MILLIONS OF US$

Imports / Exports	Algeria	Egypt	Libya	Morocco	Tunisia	Total Exports to other NACs	Total Country Exports
Algeria	-	3.5	33.3	29	102.6	168.4	8164
Egypt	13.3	-	5.7	3.4	18	40.4	2646
Libya	10.2	1.2	-	8.9	16.8	77.5	-
Morocco	0.2	0.5	84.7	-	48.5	133.9	3336
Tunisia	64.6	2.2	128.6	22.8	-	211.2	2919
Total Imports from other NACs	88.3	7.4	245.3	64.1	185.9	631.4	-
Total Country Imports	7395	7445	-	5484	4350	-	-

* SOURCE / GATT - INTERNATIONAL TRADE CENTER (1991)

Industrial co-operation should aim at full utilization of the existing industrial capabilities and co-ordinated approach to upgrading existing capabilities and/or introducing new industries.

From the view point of utilization of nuclear energy for seawater desalination, the prime areas of regional co-operation are: legal framework, manpower development, regional participation, acquisition and financing, research and development. These are briefly discussed below.

13.3.1 Legal Framework

Amongst the preparatory steps required for the implementation of a nuclear power programme, it is essential that consideration be given at the earliest stage to the legal and administrative aspects thereof in order to achieve the timely establishment of an adequate legal framework and infrastructure within which the execution of nuclear power projects may be carried out, subject to appropriate authorization, co-ordination, control and supervision [22].

The major components of nuclear legislation can be identified as dealing with the following topical areas respectively:

- Licensing requirements and other regulatory aspects such as radiological protection, nuclear safety, environmental protection, transport of radioactive materials, radioactive waste management, physical protection of nuclear materials and facilities, state system of accounting for and control of nuclear materials.
- Liability to third parties for nuclear damage and financial security covering such liability.

This constitutes a highly country-specific area, where each state has to develop its own legal structure. A co-operative approach towards developing national legislation does not seem to be applicable, nevertheless mutual consultations could be of benefit, and it would certainly be necessary to have a good knowledge of the respective legislative frameworks, in order to facilitate the smooth development of joint undertakings. This could be facilitated by the fact that most of the NACs are already parties to several international agreements related to safety, safeguards and technical co-operation.

13.3.1.1 Licensing and other Regulatory Aspects

Regulatory actions and licensing of nuclear installations constitute a national responsibility which cannot be transferred to anyone nor shared internationally. Each country has its own regulatory and licensing authority, with its own system, structure, rules, regulations, guides and procedures. There is also a regional and international responsibility. Much, however, can be done in developing a common approach and regional co-operation, which in turn can be of very large benefit to all parties involved.

Indeed, one of the problems which make it difficult to achieve international standardization of nuclear power plant designs, is the existence of different regulatory requirements in different countries. Efforts to develop internationally applicable and acceptable safety standards and similarity in regulatory systems and structures, have not been successful to date, possibly due at least partly to the fact that changing regulations, once established, are strongly resisted by all concerned.

The North African countries have as yet no nuclear power plants, therefore they do have the opportunity of building-up their regulatory structures adopting a joint approach and establishing similar or possibly even the same rules and procedures. This would undoubtedly be to their mutual benefit not only through facilitating very much the exchange of experience and mutual assistance, but also through making it possible to undertake the implementation of repeat projects without having to introduce design changes due to different regulatory and licensing requirements. Such a situation would also act as a strong incentive to reactor designers and vendors, because it would indicate the possibility and even probability of repeat orders. Thus, engineering efforts and corresponding costs could be shared among several projects.

13.3.1.2 Third Party Liability

In as much as the establishment of licensing conditions and regulatory control is essential for ensuring the safety of nuclear installations, the adoption of legislative provisions to govern liability to third parties for nuclear damage is to be regarded as a pre-requisite to the introduction of nuclear power.

Nuclear liability is usually covered in most countries with nuclear power plants, by either signing (and ratifying) the corresponding Vienna or Paris Conventions, or by enacting national legislation following the principles laid down in these conventions. The Vienna Convention came into force on 12 November 1977, and on 27 April 1992, a Joint Protocol relating to the Application of the Vienna Convention and the Paris Convention entered into force.

Out of the five NACs, only Egypt is a party to the Vienna Convention (ratified 5 November 1965) and the Joint Protocol (ratified 10 august 1989). Morocco is a signatory of Vienna Convention (30 November 1984) and the Joint Protocol (21 September 1988), but it is not party to either of them because the signature was not ratified

The specific area of liability for nuclear damage is an example where joint or at least similar approach would be of mutual benefit. In this respect, a good starting point could be signing and ratifying the Vienna or Paris Conventions and the Joint Protocol.

13.3.2 Manpower Development

The availability of sufficient number of qualified manpower at the time when it is needed is one of the essential requirements of the success of any nuclear power programme in the reliable production of electrical energy (and/or potable water) and the development of national infrastructure.

Specialized knowledge and excellence in human performance is required in all phases of a nuclear power programme. Without qualified manpower no nuclear power programme can be planned, built or operated properly, and there can be no assurance of the safety and reliability of nuclear power.

Any country embarking on a nuclear power programme has the prime responsibility for planning and implementing its manpower development programme, which must begin at the earliest stages of a nuclear power programme because of the long lead-times involved in developing highly qualified manpower [63].

Development of an adequate manpower infrastructure requires a long time and major efforts. If these efforts can be shared, it would certainly benefit all concerned. This area therefore is another one, where regional co-operation should be seriously considered. Co-operative approaches can be applied both to the desalination plants and, especially, to the nuclear reactors. In addition to sharing of resources and of experience, regional training centers equipped with sophisticated training facilities such as simulators, could be of substantial benefit to all.

13.3.3 Regional Participation

Every country has the overall responsibility for the planning and implementation of its national nuclear power programme. Without national participation it .cannot carry out this responsibility. The extent of such participation will significantly depend on the existing infrastructure capabilities and on the availability of local resources for the supply of necessary materials, services, equipment and qualified manpower [22].

As indicated in Chapter 10, a major goal identified by NACs is the achievement of eventual self-sufficiency in design, manufacturing, operation and maintenance of NPPs. The most important factor influencing the regional participation programme is the degree of regional co-operation and integration. In this respect strong commitment of all Governments of the NACs to a joint nuclear power programme is essential.

Regional and/or national participation aims at maximizing regional (or local) share not only in manufacturing processes, but also in all other activities that can be evaluated by many such as: construction, erection, commissioning, operation and maintenance. However, the degree of regional involvement in nuclear power development will be a process in which the local participation is gradually increased as the nuclear programme develops. The possibilities of joint regional activities regarding regional participation areas are briefly discussed below.

13.3.3.1 Regional Manufacturing

From the very start of the nuclear power programme, including desalination, the importance of local participation must be fully appreciated. One of the essential factors defining the programme viability will be the extent to which industrial capabilities are available and/or can be made available in the country [22].

The interests and benefits expected from local participation have to be balanced against the risks of potentially higher costs, schedule delays and deficient quality of workmanship. This requires detailed and in-depth analysis of the capabilities of local industrial infrastructures for the possible provision of goods and services required. Therefore, right at the start of the decision-making process the responsible authorities must take stock of the situation with a thorough survey of national industries and realistic assessment of their present and potential capabilities.

It seems advisable to consider this area from the regional point of view, because this would effectively increase the size of the potential market. Otherwise, considering each country separately, the more limited individual markets might not fully justify the costs and effort involved in upgrading the relevant industries, which in most, if not in all cases, would be needed to meet the high quality and technical capability targets.

To assess the present and potential capabilities of the national industries, which constitute the main objective of the survey, the methodology should be well defined. This could consist of:

- Listing all components of the nuclear power project.
- Definition for each component of the relevant standards and key design parameters, such as quality class, special testing requirements, significant manufacturing /construction materials requirements, delivery time, cost order of magnitude, etc.
- Inspection by a qualified team of a selected and representative number of national manufacturing firms and the production of documentation describing the facilities, organization, production equipment, quality control practices, etc., of each firm.
- Visits by qualified representatives of the national manufacturing industry to similar foreign industrial establishments.

- Identification for each component of present and prospective manufacturers. This would indicate those manufacturing areas more in need of development, where promotion may then be concentrated.
- Definition of the present and potential manufacturing capabilities of each firm inspected.

Manufacturing firms can be classified according to their capabilities currently available, attainable with little effort, attainable with major promotional effort, or unlikely to be attained.

13.3.3.2 Standardization of Design

To avoid dispersion of efforts on several types of reactors, the Region should decide on using one type only e.g. PWR, BWR, PHWR, etc. The policy as to plant power level should be based on standardization, the benefits being a larger market for regional industry, investment cost reduction, quality improvement, lead-time reduction and better operation. The first nuclear programme to adopt this approach was the French programme which is now quantitatively the largest one launched by a utility in the world.

The benefits of a joint approach are not limited to nuclear reactors, they could also be applied to desalination plants. Sharing of experience, mutual assistance, reduction of engineering effort and costs through repeat projects, do open-up the possibility of reducing the costs of product water.

Even if regional co-operation would only be limited to sharing of experience and learning from each other, substantial benefits could be expected.

13.3.3.3 Construction, Erection and Commissioning

The relevant tasks and activities to be performed during construction, erection and commissioning, are evidently strictly project-oriented. A regional co-operative approach to undertake them does not seem indicated, as it might dilute responsibilities and lead to problems or even failure.

There are, however, excellent opportunities for the transfer of knowledge, skills and experience, which ultimately would result in mutual benefits to all countries of the region, even if not directly involved in a particular project.

13.3.3.4 Operation and Maintenance

While on a regional level, there can be no sharing of responsibilities regarding the direction, supervision and actual performance of operation and maintenance activities, there is much room for sharing of experience and for learning from each other. This would be especially important in the case of eventual repeat-orders, based on the standardization approach.

13.3.3.5 Quality Assurance and Quality Control

A nuclear power project involves more stringent requirements for quality than would apply to a conventional project. The overall responsibility for ensuring the fulfillment of the quality requirements is placed on the owner. The regulatory authority in turn has to ensure that the owner complies with his duties and responsibilities.

Quality assurance (QA): is defined as the planned and systematic actions necessary to provide adequate confidence that an item or facility will perform satisfactorily in service.

Quality control (QC): is defined as the quality assurance actions that provide a means to control and measure the characteristics of an item, process or facility in accordance with established requirements.

QA is always the responsibility of the organization that has the final technical, administrative and financial responsibility for the plant. This organization is usually the plant owner. However, the need for substantial regional manufacture means that the NACs should start developing specific QA/QC codes of practice for the Region, which should be acceptable, and if possible mandatory within the Region, in order to escape from the current fragmentary situation.

13.3.4 Acquisition and Financing

The acquisition process of complex technology installations is time consuming, costly and requires expertise which is usually not fully available in developing countries. The use of foreign specialized engineering or consultancy firms is the approach adopted practically in all cases. This tends to lead to "custom made" projects covering a broad range of quality. Experience shows that while some projects are highly successful, others are costly failures.

Regional co-operation through participation in the acquisition phase of projects, at least in the development of bid invitation specifications and in the evaluation of bids, would certainly increase local capabilities, tend to avoid the repetition of mistakes, and promote the achievement of success. It would also promote a trend towards standardization. In bilateral projects, a joint approach and full participation in the acquisition process by the two partners is obviously assured, but it does not have to be limited to the parties directly concerned. Others could also be involved at least in an observer or advisory capacity.

Regarding financing, taking into account that very large investments are required, sharing of the financial load and eventually also the benefits expected, might very well facilitate solving this problem.

13.3.5 Research and Development

It is an undisputed fact that research and development played a vital role in launching nuclear power. No developed or developing country has ever initiated a nuclear power programme without first having established a nuclear research and development organization. Such organizations play an important and, in most cases, a leading role in the success of national nuclear power programmes.

Nuclear research institutes vary from country to country, differing in size, goals, roles, scope, facilities etc. In developing countries, they are usually more modest than in highly developed countries with ongoing nuclear power programmes. The possible role of such institutes in the nuclear power programmes for developing countries, where the industrial infrastructures are not yet sufficiently developed, could be the following:

- Provide the government and utilities with technical information and support on nuclear science and engineering.
- Support nuclear-safety-related activities in particular.
- Participate in nuclear manpower development, especially by offering courses, seminars and on-the-job practical training in laboratories.
- Assist industries in selecting adopting and/or adapting new technologies.
- Develop indigenous technical capabilities and know-how, with the aim of enhancing national participation.
- Provide a base for basic and applied research in areas of priority interest for the country.

- Provide scientific and technical services in such areas as materials testing, analysis, special studies, inspections etc.
- Act as an information gathering and distribution center on nuclear matters.

Again this is an area where regional co-operation would be very beneficial. Regional co-operation could take various forms such as: sharing the experience and consultations, co-ordinated research programme utilizing existing R&D institutes in each country or the establishment of a joint R&D Institute. Other forms of co-operation could be through the enhancement of the role of the Arab Atomic Energy Authority (AAEA), which provides a good forum for advancing peaceful uses of nuclear energy in the Arab World. Currently, only Egypt, Libya and Tunisia out of the five NACs are members of the AAEA.

An active regional participation in relevant IAEA studies and activities as well as in an eventual Nuclear Desalination Demonstration Facility would not only sustain the international interest in the subject, but would also provide the NACs with first hand experience and knowledge of possible problems and solutions related to nuclear desalination. NACs could offer a site for the demonstration facility, provide funds and carry out non-nuclear demonstration of technical viability of proposed coupling schemes.

13.4 PROPOSED JOINT REGIONAL PROJECTS

In the preceding section areas of co-operation between the NACs were briefly discussed. To implement the suggested co-operation, it is necessary to create the proper organizational structure/framework to bring these ideas into being. Possible regional projects and/or organizational framework are presented below.

13.4.1 Regional Working Team of Licensing and Safety Experts

It is possible to establish a common regulatory approach for the region as a whole without compromising the requirements of any single country. Such a regulatory approach should be developed jointly to be accepted on a regional basis, especially as a number of the proposal sites for nuclear power and nuclear desalination plants lie in the border areas and are likely to supply the needs of more than one country.

13.4.2 Regional QA/QC Commission

The current fragmented approach to QA/QC, not only in the region as a whole but also within each individual country, makes it difficult to broaden the regional manufacturing base, particularly for nuclear projects. Therefore, the NACs should start developing specific QA/QC codes of practice for the region.

It is recommended to establish a QA/QC commission of relevant experts from industry, licensing authorities and research centers within the NACs to develop specific regional QA/QC codes of practice. These codes should be based on internationally accepted best practice. A suitable framework could be the latest edition of QA documents for nuclear plants and systems.

13.4.3 Unified Regional Power System (URPS)

A unified power system between Algeria, Morocco and Tunisia already exists. Plans are under way to link the Libyan grids with those of Egypt and Tunisia. This should be supplemented by unifying the all grids to create a URPS. A regional electrical planning commission should then be established to plan future regional expansion plans of the URPS.

13.4.4 Regional Project Support and Management Companies

Based on the regional experience in executing power plants and water projects, and the experience of other developing countries with similar industrial infrastructure, as well as the consideration of financing, guarantees and contractual responsibilities, it is suggested to adopt the framework outlined in Figure 32 to carry out localization of power plants and desalination projects. The proposed framework is based on the establishment of two companies, namely, Electric Power and Desalination Engineering Company (EPDE) and Equipment Manufacturing Engineering and Management Company (EMEM).

13.4.4.1 Electric Power and Desalination Engineering Company (EPDE)

This engineering company would have the following responsibilities:

- Basic design of the plant as well as laying down the specifications for the various packages and main components.
- Evaluation of bids to carry out various packages and main components, and recommendations on selecting the winning bidders.
- Project Management including control of various interfaces between executing companies as well as interfaces between those companies and the owner.
- Provide engineering services including QA/QC, start-up, testing.

It is recommended that EPDE be established as a joint venture company between authorities and companies of electricity and water sectors within the NACs, and one or more foreign (international) partner (see Figure 33). The foreign partner should be chosen based on regional considerations, with the aim of gradually replacing the foreign experts by regional experts through a well defined technology transfer programme.

EPDE will be of a limited capital, therefore, it can not bear the responsibilities of a main contractor for executing the project or subcontracting other companies to execute the various packages. Contracting should in this case be done directly between the owner and the executing companies. Thus the source of finance will be the owner, and in the mean time the executing companies will bear all responsibilities and guarantees of executing the project including all types of penalties.

13.4.4.2 Equipment Manufacturing Engineering and Management Company (EMEM)

This is the second company suggested in the localization framework indicated in Figure 32. The main proposed responsibilities are:

- Design of equipment and components as well as laying down the manufacturing specifications.
- Evaluation of bids to manufacture and/or develop equipment and components to choose the best bidders, or negotiate directly with manufacturing companies. In either case firm contract proposals should be reached.
- Management of local manufacturing of power and desalination plants, equipment and components including allocating the various components to various manufacturing firms and co-ordination of interfaces.
- Specify and supervise quality requirements.
- Assisting local industries in developing their capabilities to meet the needs of electricity and water sectors of power and desalination plants as well as merging local and foreign companies together if needed.

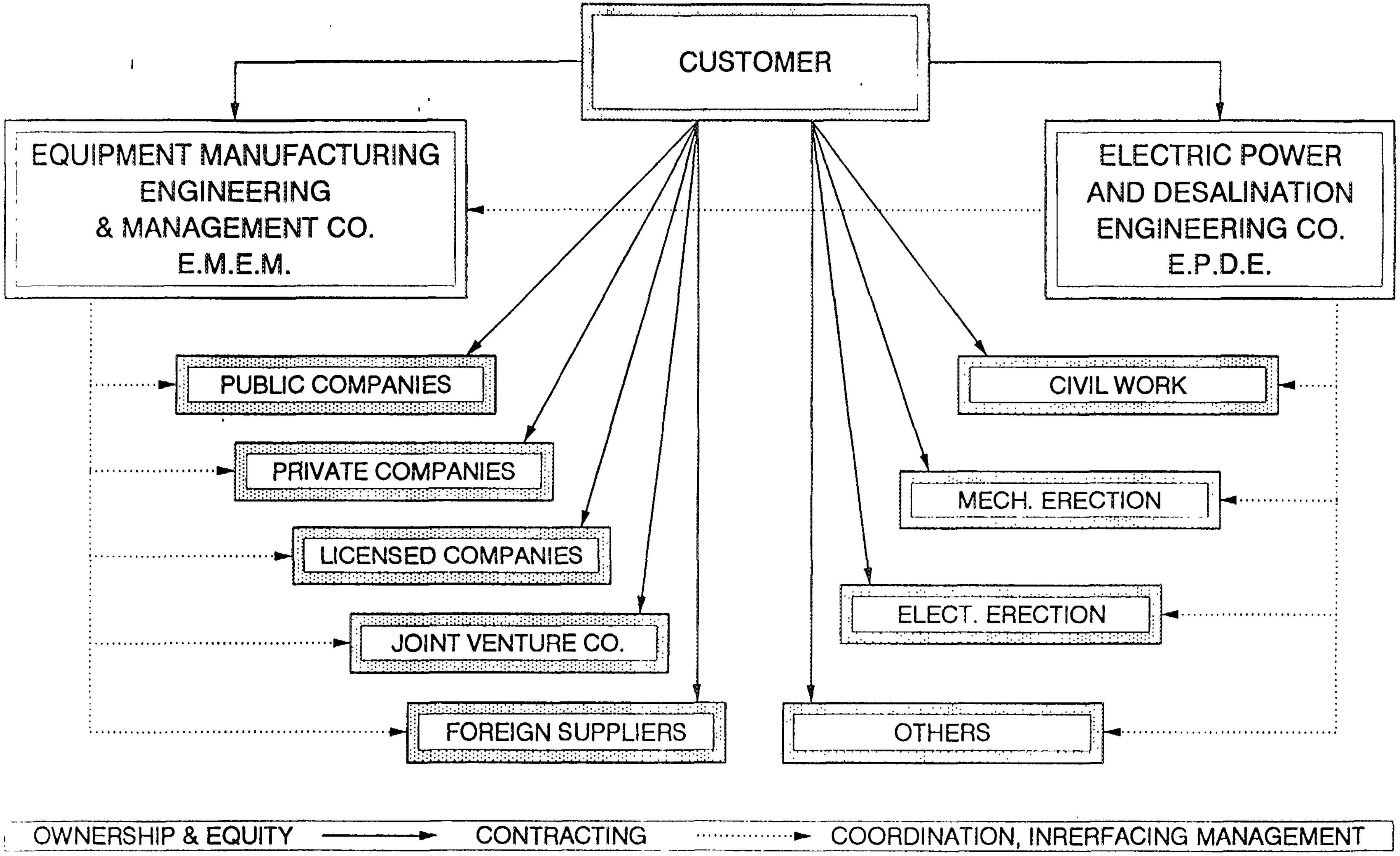


Fig. 32: *Flow diagram of customer, EPDE, EMEM and manufacturers relationships*

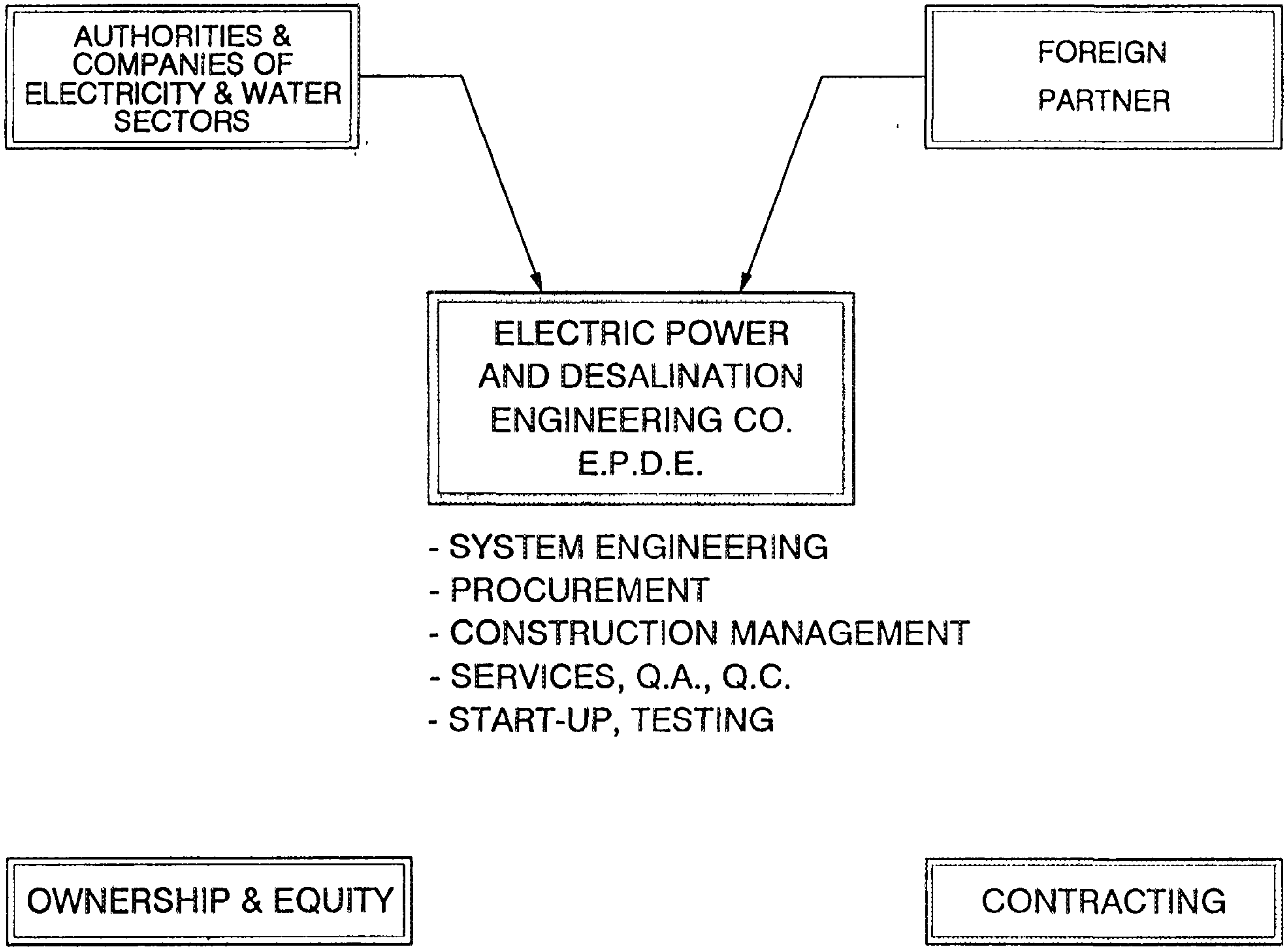


Fig. 33: *Ownership of EPDE*

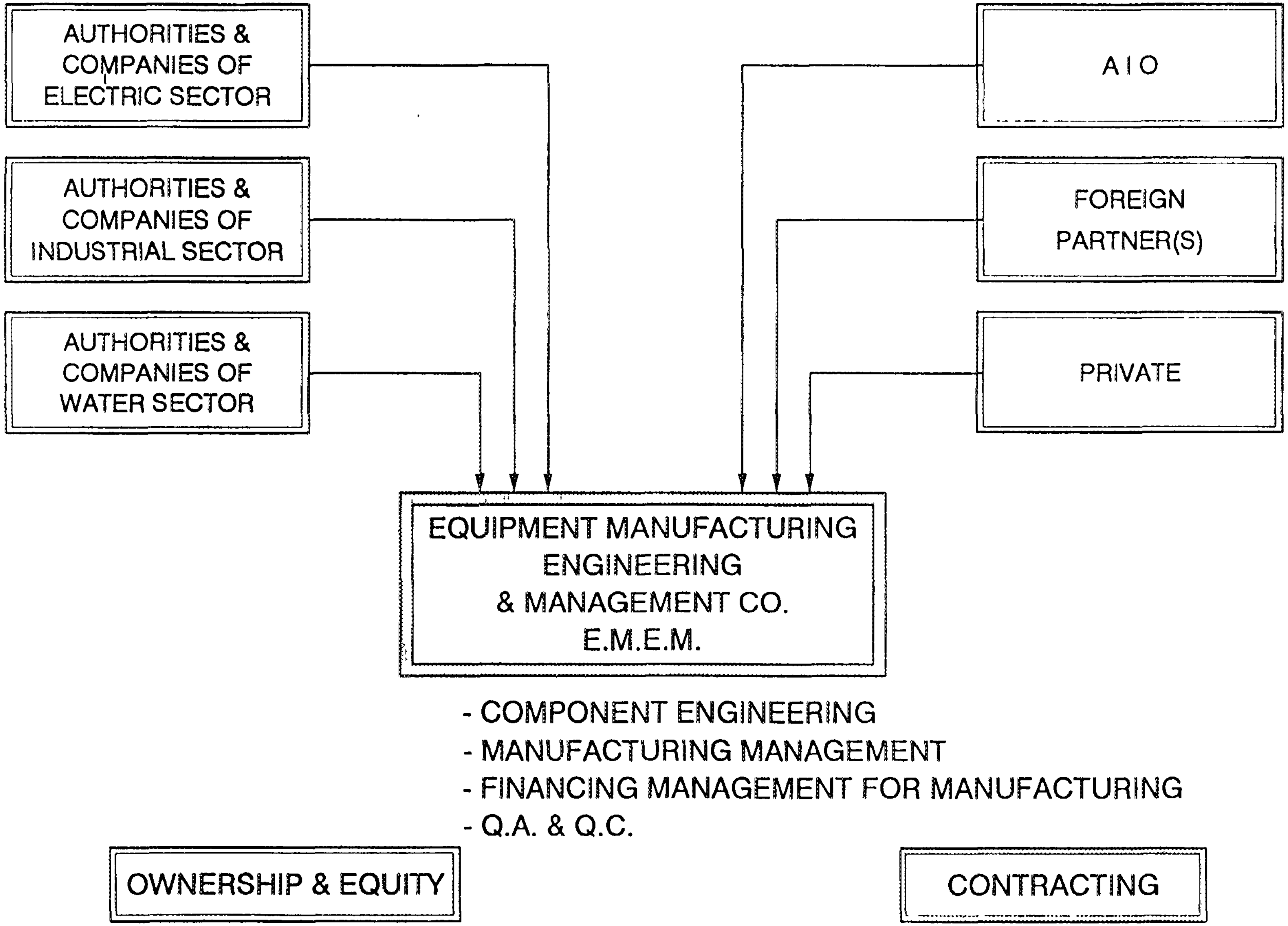


Fig. 34: *Ownership of EMEM*

It is recommended that EMEM could be established as a joint venture company between users, manufacturing companies (public or private), and a foreign partner (or partners) as shown in Figure 34. In this respect the Arab Organization Industrialization (AOI) can set an example, play an important role as a sophisticated manufacturing organization owned by several Arab Governments.

The relationship between EMEM, the owner and the manufacturing companies is also shown in Figure 32. All contracts are concluded directly between the owner and the manufacturing firms.

13.4.5 Joint Training Center

A well planned, co-ordinated and implemented regional manpower development programme not only benefits the region by producing the necessary skills and capabilities to perform the tasks required for nuclear power programme, but also has the effect of raising the general level of education, scientific/technological and industrial infrastructures, which provides the basis for the implementation of the nuclear manpower development programme. In general, basic training can be provided by the existing educational and training facilities, probably with some modifications to the existing curricula and standards.

There are also many advantages in establishing regional or joint nuclear training centers. The purpose of such a center would be to provide specialized training for professionals, technicians and craftsmen in those technical areas needed for nuclear power programme, including nuclear desalination. The nuclear training center may also be associated with one of the nuclear research and development institutes within the NACs, such as Ain-Oussera in Algeria, Inshas and El-Dabaa in Egypt and Tajoura in Libya. The activities and facilities of the joint training center must be oriented to training manpower for the nuclear power programme, and should be open to all international efforts related to the peaceful application of nuclear energy. The teaching staff of the training center could be selected from experts and delineation disciplines.

13.4.6 Joint Drought Fund

As stated in Chapter 12, providing the foreign component of investment for nuclear power projects in the NACs, including nuclear desalination, from international markets could be problematic. Therefore, the NACs will have to depend on their own resources. A relevant example is the establishment of the Alternative Energy Fund of Egypt.

During the course of the present feasibility study, the Libyans proposed the establishment of a regional fund in an international institution such as the World Bank or the African Development Bank, to finance water development projects including desalination (nuclear or conventional) in the five countries. NACs contribution would be based on GNP of the respective country.

The idea is good but more details would have to be worked out before it could be implemented. Therefore, a first step should be setting up a team of financial experts from the region to work out the technical details and provide clear recommendations to the decision makers.

14. SAFETY, REGULATORY AND ENVIRONMENTAL ASPECTS

14.1 GENERAL

Desalination technology is a mature, proven and commercially available technology. It is used in the Middle East and North Africa and extensively in the Arabian Peninsula, which has about 60% of the world desalination capacity. The energy source used is fossil fuels (gas and oil), because they are readily available and cheap. The regulatory, quality and environmental concerns typical of conventional technology are widely known in the region and will not be dealt with here.

The use of nuclear energy (or fissile energy) as an energy source to the desalination process is feasible. The safety, regulatory and environmental concerns in nuclear desalination are mainly those related to nuclear power plants, with due consideration to the coupling process.

Currently there are no nuclear power plants in the NACs, though feasibility studies and siting work were undertaken in all the region. Research reactors in operation and under construction exist in Algeria, Egypt, Libya and Morocco. Actions are being taken to introduce a research reactor in Tunisia. Waste management technology is available in several countries, radiation protection and nuclear legislation exists to varying extent in NACs. However, in view of the great interest in nuclear desalination in these countries, it is important to review recent developments in safety and address some problems related to safety, regulatory and environmental aspects, as well as some safety issues.

14.2. RECENT DEVELOPMENTS IN INTERNATIONAL NUCLEAR SAFETY

14.2.1 Introduction

The consequences of the TMI (1979) and Chernobyl (1986) accidents have emphasized the need for common safety principles for all nuclear installations, particularly nuclear power plants. The International Nuclear Safety Advisory Group (INSAG) was formed by the Director General of the IAEA in 1985. The main functions of INSAG are:

- To provide advice on the fundamental principles upon which appropriate nuclear safety standards and measures can be based.

- To provide a forum for the exchange of information on generic nuclear safety issues of international significance.

- To identify important current nuclear safety issues and to draw conclusions on the basis of results of nuclear safety activities within the IAEA, and other information.

- To give advice on nuclear safety issues in which an exchange of information and/or additional efforts may be required.

The IAEA published in 1988 the INSAG-3 report [93]. Since nuclear safety requires a continuing quest for excellence, this quest should be directed towards reducing risks to the lowest practical level and should be based on understanding of the underlying objectives and principles of nuclear safety. The INSAG report [93] contains a logical integrated safety framework which includes concepts of safety objectives, use of probabilistic safety assessment, reliability targets for safety systems and promotes safety culture. Recently the IAEA issued Safety Series - 110 [94] on the safety of nuclear installations in the Safety Fundamentals Series, which is the highest hierarchy in the Safety Series Publications. It takes account of the INSAG-3 report and sets the basic objectives and fundamental principles for ensuring nuclear safety. The following sub-sections summarize the important developments in nuclear safety in the international arena.

14.2.2 Safety Objectives

The definition of the three nuclear safety objectives for nuclear installations [93, 94] is an important development. The first objective is general and is supported by two complementary objectives dealing with radiation and technical safety aspects. These objectives are interdependent to ensure completeness and emphasis:

- General Nuclear Safety Objective: To protect individuals, society and the environment from harm by establishing and maintaining in nuclear installations effective defences against radiological hazards.

- Radiation Protection Objective: To ensure that in all operational states radiation exposures within the installation or due to any planned release of radioactive material from the installation is kept below prescribed limits and as low as reasonably achievable and to ensure mitigation of the radiological consequences of any accident.

- Technical Safety Objective: To take all reasonably practicable measures to prevent accidents in nuclear installations and to mitigate their consequences should they occur; to ensure with a high level of confidence that, for all possible accidents taken into account in the design of the installation, including those of very low probability, any radiological consequences would be minor and below prescribed limits; and to ensure that the likelihood of accidents with serious radiological consequences is extremely low.

Since the operation of a nuclear installation must be presumed to involve some probability of an accident with a radiological consequence and the exposure to a dose of radiation must be presumed to result in some probability of fatal cancer, the safety objective requires that everything must be done to ensure that doses or risks (or the harm) are as low as reasonably achievable [95]. The dose limits should take into consideration the Basic Safety Standards (BSS) [96, 97] for protection against ionizing radiation and for the safety of radiation sources, SS 115 (1996).

It is essential to recognize the importance of prevention of accidents and to realize that the protection of resources invested in a nuclear installation is of high societal importance and demands careful attention to all safety issues. The accidents at TMI and Chernobyl have caused severe losses of investments and demanded huge resources in mitigation and decontamination efforts. Such expenses cannot be afforded by the economies of many countries, including the NACs. Further, on the international scale, the nuclear industry suffered serious set backs following TMI and Chernobyl. The adverse public opinion against nuclear energy must be convinced by clear technical evidence that the level of nuclear safety is sufficient and acceptable for healthy development of nuclear power, particularly in countries which suspended nuclear power programmes including countries in North Africa.

14.2.3 Safety Fundamentals

To achieve the safety objectives, INSAG-3 [93] developed 62 basic safety principles which state how this achievement can be undertaken. These principles were grouped and condensed to 25 fundamental principles in Safety Series - 110 [94].

14.2.4 International Conventions

Accession to a number of international convention would facilitate the introduction of a nuclear power programme, even they do not have mandatory charter as non-proliferation commitments and IAEA safeguards. These conventions came into being through a general desire among many nations to obtain assurance that strict standards for nuclear safety and physical protection against theft of nuclear materials or sabotage are applied everywhere and that would be mechanisms for notification and assistance in case of an accident in any country. This is the reason why some countries which do not have nuclear power plant s have also acceded to them. The same will likely apply to the convention on radioactive waste management and disposal which is now being worked out under the aegis of the IAEA. The most relevant international conventions are the following:

- Convention on Early Notification of a Nuclear Accident.
  Sets up the orginizational and communications links with IAEA and neighboring countries in the event of a nuclear accident (in force since 1986).

- Convention on Assistance in the Case of a Nuclear Accident or Radiological. Emergency set up co-operation links between countries for assistance in case of an accident (in force since 1987).

- Convention on Physical Protection of Nuclear Material.
  Obligates parties to make arrangements and follow define standards for physical protection of nuclear materials and nuclear facilities (in force since 1987).

- Convention on Civil Liability for Nuclear Damage.
  Set up the principles for third party liability and insurance for the operators of nuclear installations (established in 1963, currently under review).

- Nuclear Safety Convention.
  Obligates parties to follow fundamental safety principles for nuclear power plants and to report on the implementation of safety measures to a conference to be held periodically.

- Radioactive Waste Management Convention.
  Now being developed, parallel to nuclear safety convention.

Accession to relevant international conventions implies commitments by the government and the plant operator, and will facilitate international co-operation and technology transfer.

14.2.5 IAEA Safety Standards

14.2.5.1 NUSS Programme

The nuclear safety standards programme deals with establishing Codes of Practice and Safety Guides for nuclear power plants. It provides member states with guidance on the safety aspects associated with thermal nuclear power plants. They are recommendations for use in member states in the context of their own nuclear safety requirements. They are essential for the application of the Safety Fundamentals. The codes establish the objectives and minimum requirements that should be fulfilled to provide adequate safety in the operating nuclear power plants. They are five codes covering the following topics:

- Governmental organizations for the regulations of nuclear power plants.
- Safety in nuclear power plant siting.
- Design for safety of nuclear power plants.
- Safety in nuclear power plant operation.
- Quality assurance for safety in nuclear power plants.

Under each code a number Safety Guides exist which describe and make available to Member States acceptable methods of implementing specific parts of the relevant Codes of Practice. The number of NUSS document is about 50. NUSS provides guidance to the application of the safety fundamentals.

14.2.5.2 Other related IAEA Safety Series

Other related IAEA Safety Services to support nuclear and radiation safety should be consulted. It is important to mention safety of nuclear research reactors [98] since many of the proposed reactors for desalination can at this stage be considered research reactors.

14.2.6 International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources

This document, called BSS [96, 97] has been jointly sponsored by six organizations (FAO, IAEA, ILO, NEA/OECD, PAHO and WHO) to harmonize radiation safety, and was approved by the IAEA Board of Governors in September 1994. These standards supersede any previous documents in the field of radiation safety. The aim of the BSS is to prevent the occurrence of deterministic effects of radiation and to restrict the likelihood of occurrence of stochastic effects. The practices to which the BSS apply include the generation of energy by nuclear power comprising any activity in the nuclear fuel cycle which involves or could involve exposure to radiation or radioactive substances. The dose limits established by the BSS are intended to ensure that no individuals committed to unacceptable risk due to radiation exposure. The dose limits are those of 1990 ICRP recommendations. It includes technical requirements: security of sources, defence in depth and good engineering practices. It also includes management requirements emphasizing safety culture and quality assurance. The BSS also provides guidance for application of safety fundamentals.

14.2.7 Safety Culture

The term safety culture was mentioned for the first time in 1986 in the INSAG-1 Report [99] concerning the Chernobyl accident. One of the main INSAG conclusions was: "There is a need for a 'nuclear safety culture' in all operating nuclear power plants". It emphasized the creation and maintenance of nuclear safety culture as a reinforcement process which should be used in conjunction with the necessary disciplinary measure. The root cause of the Chernobyl accident was in the failure of the human element.

In the INSAG-3 report [93] a fundamental safety principle on safety culture was introduced which states: An established safety culture governs the actions and interactions of all individuals and organizations engaged in activities related to nuclear power. As defined in INSAG-4 [100] safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear safety issues receive the attention warranted by their significance. Principle 4 includes, though implicitly, safety culture. It is important for NACs embarking on nuclear desalination, and probably nuclear power programmes, to adhere to the safety culture principle and to work towards establishing and maintaining nuclear safety culture in all organizations involved in nuclear power and even in research reactors.

Nuclear technology has raised extensively the importance and necessity of safety, quality and reliability, a trinity which is a must for nuclear technology to progress and excel. This trinity has been incorporated into an ideology or culture the "nuclear safety culture" to ensure personal dedication to this trinity, which is diffusing to other technologies. Safety culture flourishes in an environment of openness and good communications [101].

14.2.8 Nuclear Safety in NACs

In view of recent developments in international nuclear safety and the importance of safety culture and the advent of the International Nuclear Safety convention there is a great need of a joint study in North Africa which concentrates on reviewing existing legislative and regulatory frame work, the regulatory infrastructure, safety culture attitude with a view of formulating a work plan to strengthen all nuclear safety related activities based on the fundamental nuclear safety principles and to establish and maintain safety culture. Further a North African Safety Advisory Group (NASAG) could be established to carry out these tasks, define generic technical safety aspects of nuclear desalination and undertake technical work in these areas including probabilistic safety analysis. Further, it is important to harmonize regulatory and safety activities in this regard and to formulate, where possible, a common regional approach to nuclear desalination safety.

It is believed that the NACs' feasibility study on nuclear desalination will not be complete without giving thorough attention to safety and regulatory issues in co-operation with the IAEA and defining action plans. Investing in safety, which includes upgrading the safety infrastructure, manpower development, and strengthening the regulatory activities and establishing safety culture, is a sound and essential requirement for ensuring safety and enjoying the fruits of nuclear technology particularly in electricity and water production.

14.3 SOME SAFETY ISSUES IN NUCLEAR DESALINATION

14.3.1 Coupling

The overall safety of an integrated complex composed of nuclear reactor plant coupled to a nuclear desalination plant is mainly dependent on the safety of the nuclear reactor plant and the effect of coupling or rather the interaction between the desalination plant and the nuclear plant. This interaction should be analyzed in various coupling situations to assess its effect on the safety level of the reactor and the overall nuclear desalination system, either in normal operation or accident situation. In particular, it is vital that the design, operation and the performance of an integrated nuclear desalination plant shall ensure protection of the product water against radioactive contamination.

A brief discussion of the safety implications in various coupling situations is given below [102]:

- Electrical only coupling. As mentioned previously in case of RO or MED/VC desalination system there is no interaction between the reactor plant and the desalination plant. Thus coupling will pose no safety concern. There would be no risk of radioactive contamination reaching the potable water produced. The safety level to achieve is that of the nuclear reactor plant.

- In case of a reactor-contiguous RO system with preheat [51, 75], the operational/ physical interactions between the reactor and desalination plants are kept to a minimum. Since the condenser cooling water is discharged from the nuclear plant before it is used in the desalination plant, there is no possibility for feed back from the desalination plant to the reactor plant. Further, operational problems in the reactor plant affect only the amount of preheat in the RO feed stream and accordingly influence the efficiency of water production and do not pose any safety concern, and have no effect on the water quality. Even shutdown of the reactor does not interrupt water production capability.

- Thermal coupling: In thermal processes, energy to be supplied is mainly low temperature process steam or water. Coupling is accomplished via a heat transfer circuit. Since radioactivity exists in the steam or hot water, the risk of contamination of product water exists and must be avoided. Avoiding this risk can be undertaken by adding intermediate loop or loops which incurs additional costs. Scenarios involving failure mechanisms in materials, systems or components which could lead to carry over of radioactive materials to the product water should be determined and the risk from such scenarios needs to be assessed in order to establish the number of intermediate loops, if any, required to avoid the risk of water contamination.

This experience in thermal coupling is important and should be made available from the Aktau complex. There is also vast experience in nuclear steam generator technology and management for PWR and PHWR systems available. Similarly a vast experience exists in condensers using salt water. For adequate thermal coupling sufficient to prevent radioactive contamination of potable water these technologies should be taken into consideration.

In thermal coupling, there is also direct coupling between the reactor operation and the desalination plant operation. The shut-down of the reactor would interrupt the operation of the desalination plant. This is an economic and not a safety concern. Nevertheless it needs to be considered. Operational transients in desalination plants would have a direct physical feedback into the reactor system. Such transients could have safety implications and need to be assessed.

Thermal coupling in case of a dual purpose reactor (electricity and heat) could pose different problems which should be assessed. The turbines in a dual purpose plant have to satisfy simultaneously the requirements of electricity generation and heat generation for the water distillation systems. The safety implications should be assessed.

14.3.2 Joint Siting

Joint siting of the nuclear plant and desalination plants raises some safety concerns. The proximity of the nuclear desalination complex to population centers and its implications to emergency planning and water supply should be examined. Further, the environmental impact of the desalination plant, in particular the impact of reject brine with its high salinity and chemical content, on the reactor plant should be assessed as well as the impact on the environment, including the thermal discharges coming from both plants.

14.3.3 Demonstrated Licensability, Safety Assessment and Review

As mentioned previously, the reactor safety with due consideration to coupling and combined siting problems, is the corner stone of the nuclear desalination complex. To ensure safety and demonstrate licensability, particularly in countries which are introducing their first nuclear power plant (such as in the NACs) the reference plant approach was recommended. The type and design of reactor to be introduced should have a reference plant licensed or licensable in the vendor's country or country of origin [103]. It is preferable if the selected reactor is proven.

Demonstration of licensability is still an important and essential issue. It should be based on the following:

- The licensability in the country of origin, provided that the regulatory body of that country is assessed with the assistance of the IAEA (through for example the International Regulatory Review Team - IRRT) if this is required by the importing country regulatory body.

- Design review of the plant.

This requires the adoption of the above mentioned safety and licensing requirements by the regulatory body of the importing country.

Safety assessment and review could be undertaken in two stages which might overlap. The first stage is to be undertaken in co-operation with the regulatory body of the vendor's country using that country's licensing requirements, criteria, codes and guides, practices etc. The use of related licensing documents and assessments will be of great help at this early stage. The second stage is to be undertaken in co-operation with the IAEA based on Safety Fundamentals, NUSS Codes and Standards, BSS, etc. It must be emphasized that any assistance or advice or consultation does not relieve the regulatory body of the importing country from its licensing responsibility based on complete review. It should be capable of undertaking such independent calculations and analyses as judged necessary to verify the submitted information and to provide firm basis for making the required safety assessment.

International co-operation in safety assessment and review constitutes a sound approach in this rapidly evolving field. In desalination systems undergoing safety review or still in the design stage, early participation by interested parties is recommended.

Licensing of nuclear power plants involves considerable interactions between the nuclear regulatory authority and many national authorities. In case of nuclear desalination this will involve additional authorities dealing with water supply and regulations. It is very important to involve concerned water authorities in the NACs early in this study if this has not already been undertaken.

14.4 HEALTH AND ENVIRONMENTAL IMPACT OF NUCLEAR DESALINATION

The Health and Environmental Impact (HEI) of nuclear desalination is essentially that attributable to nuclear electricity. Comparative assessments of HEI of various fuel cycles used in electricity production is pursued by an Inter-Agency activity led by the IAEA. The Helsinki senior expert symposium on electricity and environment reviewed the situation extensively in 1991 [103]. An important recommendation is that comprehensive energy and electricity planning has to take into account the costs of HEI which are important components of the full social cost of energy supply. The symposium also recognized the importance of a major policy change towards global strategy for environmental impact reduction resulting from carbon emissions.

The comparative health impact for various fuel cycles used in generating electricity has been estimated for occupational and public risks by Fritzchte in 1989 and was summarized recently at Helsinki (Issue Paper 3) [104]. The available data implies that in normal operation electricity generation systems based on gas, nuclear or renewable energies tend to be on the lower spectrum of health risks, and those based on coal and oil on the higher spectrum of health risks (Figures 35 and 36). In case of severe accidents (excluding Chernobyl) rough estimates suggest that the health risk from nuclear, oil and natural gas fuel cycles is of the same order of magnitude and two orders of magnitude smaller than that from hydroelectric systems. These estimates were based on existing PWRs. Other reactor types, particularly the CANDU type was not considered. Recently in March 1994 Hirschberg and Parlaventzas [104] published their analysis on preliminary normalized fatality rates for severe accidents in various nuclear fuel cycles in the period 1969 - 1986 and are shown in Table 89. The highest immediate fatalities/energy which is 2 GWy(e) is for hydropower followed by fossil fuel cycles 0.39, 0.38, 0.31 for coal, gas and oil, respectively. The least value, 0.03/GWy(e), is for the nuclear (fissile) fuel cycle which is about one order of magnitude less than oil. It is expected that future reactors including desalination reactors which include advanced safety features, such as passive safety, would have even lower health impacts and the possibility of accidents with significant off-site releases is virtually eliminated.

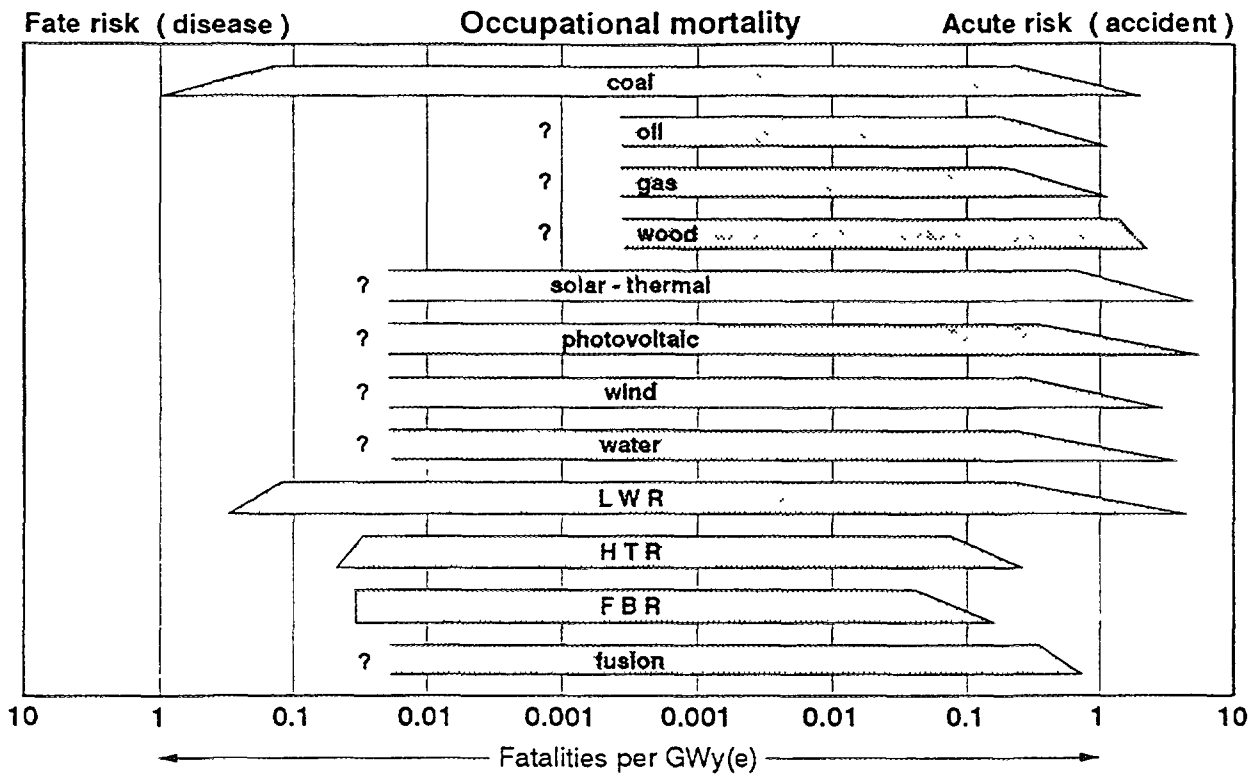


Fig. 35: Occupational mortality risks due to electricity production (all steps of the fuel cycle; without severe accidents)

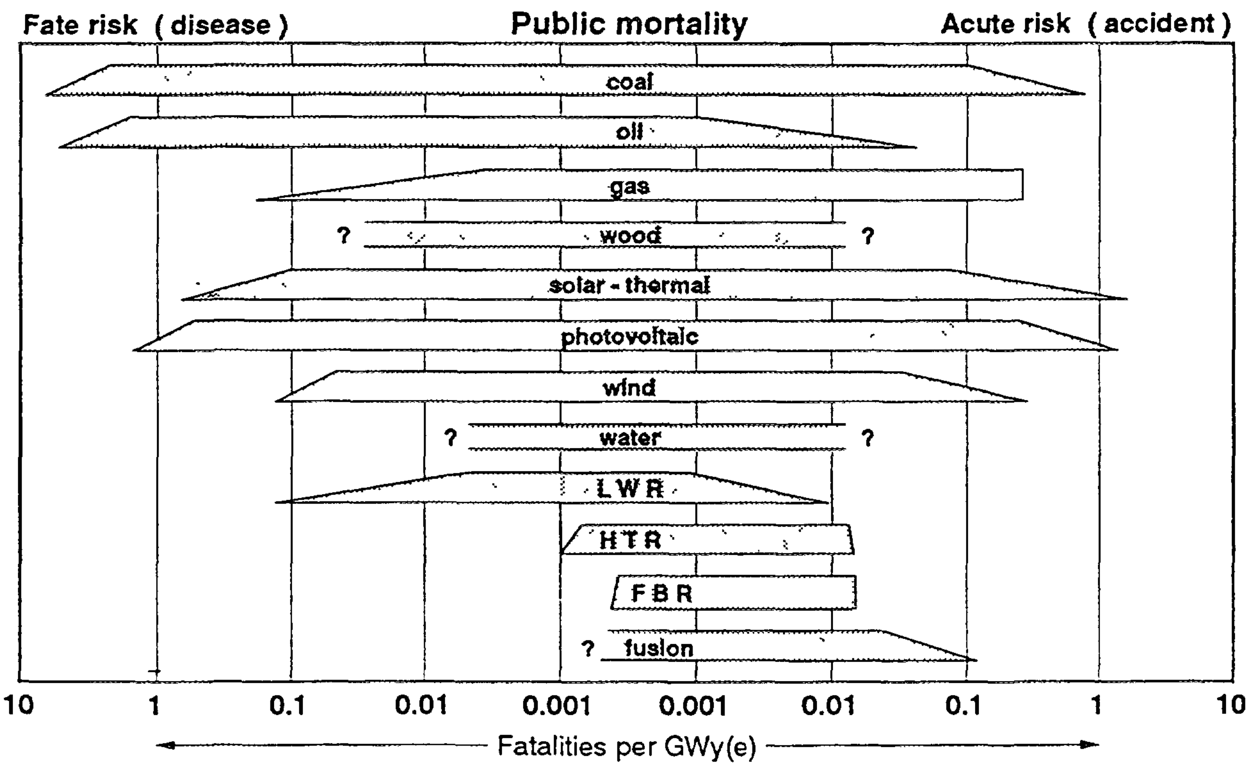
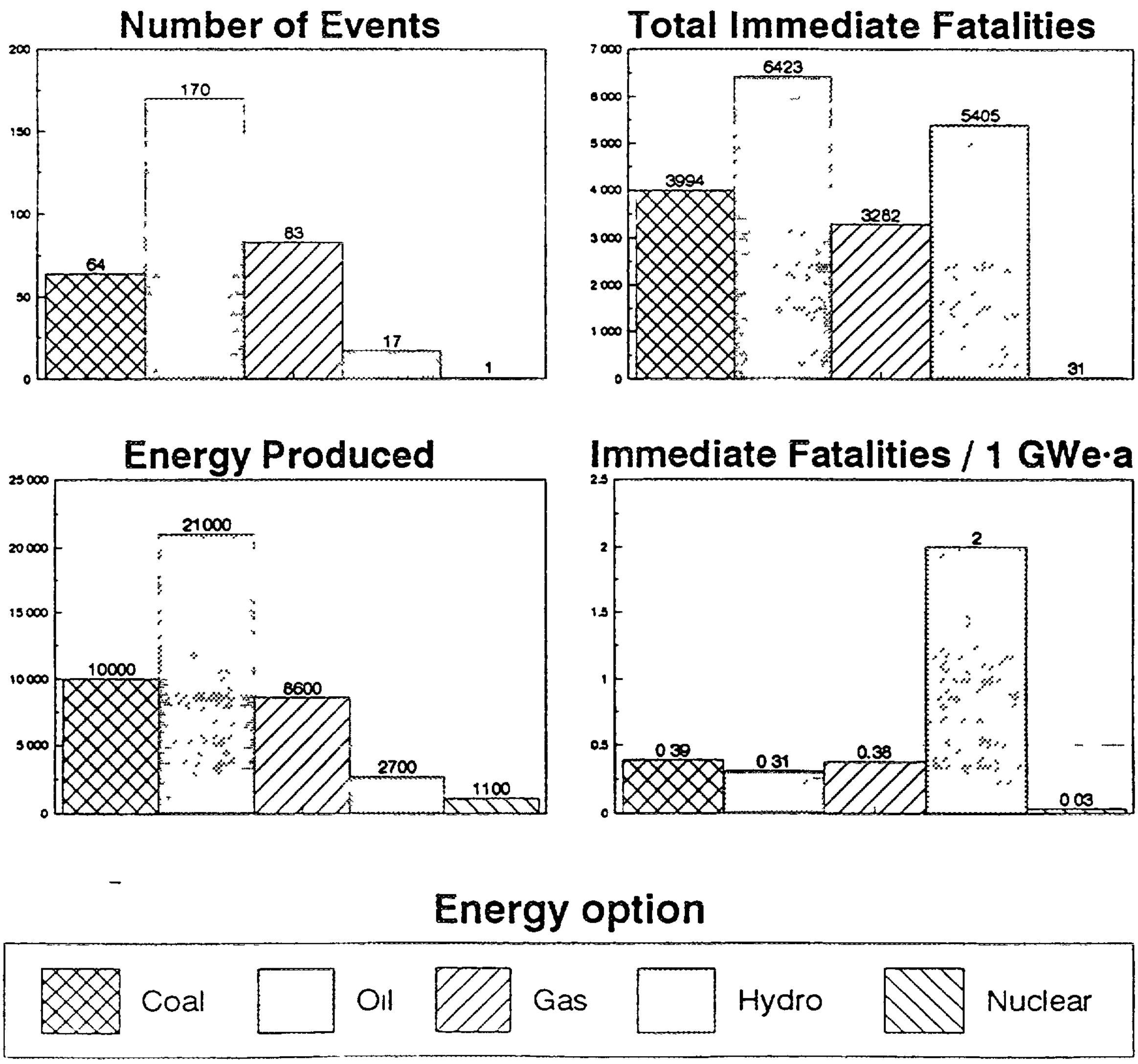


Fig. 36: Public mortality risks due to electricity production (all steps of the fuel cycle; without severe accidents)

TABLE 89: PRELIMINARY NORMALIZED FATALITY RATES FOR SEVERE ACCIDENTS (for 1969-1986, by Hirschberg and Parlaventzas, March 1994, San Diego, USA)

Energy option / Characterics	Coal	Oil	Gas	Hydro Power	Nuclear
Number of Events (#)	64	170	83	17	1
Immediate Fatalities / Event	10 - 434	5 - 2 700	5 - 550	9 - 2 500	31
Total Immediate Fatalities	3 944	6 423	3 282	5 405	31
Energy Produced (GWe·a)	10 000	21 000	8 600	2 700	1 100
Immediate Fatalities / / Energy (# / GWe·a)	0.39	0.31	0.38	2	0.03



Roughly 80% ot CO_2 comes from energy generation and thus is a major contribution to the greenhouse effect. Environmental and climate change policy trends are affecting energy policies in many parts of the world. The UN Framework Convention on Climate Changes (FCCC), the Earth Summit's document on climate change that was unanimously adopted and signed by 154 countries, is becoming a widely accepted basis for national energy strategies, i.e. to stabilize "greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with climate system". Energy policies in many countries are thus moving towards minimizing carbon emission to be as low as practically possible. This can be achieved by a package of measures including improving energy efficiency, switching to low carbon fuels and fissile fuels. Recently, several scenarios have been developed in order to make long-term projections up to the year 2100 of energy associated carbon emissions by the Intergovernmental Panel on Climatic Change (IPCC), the International Institute for Applied System Analysis (IIASA), the World Energy Council (WEC) and IAEA [105]. Global CO_2 can be substantially reduced if fissile energy can further penetrate the electricity market. Fissile electricity is one of the better options to alleviate global climatic change.

Desalination is an energy intensive process. Nuclear desalination can be one of the good options to reduce CO_2 emissions. In the Mediterranean assuming alone, the daily water production of 10 million m^3 up to the year 2000, using fissile instead of fossil fuels, the following emissions could be avoided:

2.0 Megatons of CO_2 per year;
0.2 Megatons of SO_2 per year;
0.06 Megatons of NO per year;
0.016 Megatons of HC per year;

14.5 RECOMMENDATIONS

1. Formation of a North Africa Safety Advisory Group (NASAG) to give advice on nuclear safety issues related to nuclear desalination. This can include, but is not necessarily limited to, the following tasks:

   a) To review existing legislative and regulatory framework and infrastructure; safety culture attitudes with a view of upgrading and improving the situation; to undertake the necessary safety and regulatory tasks connected to nuclear desalination; and to establish and maintain safety culture, based on the INSAG-3 Safety Culture Principle and INSAG-4 document. An established safety culture governs the actions and interactions of all individuals and organizations engaged in activities related to nuclear power.

   b) To harmonize regulatory and safety activities in the region, and to formulate, where possible, a common regional approach to nuclear desalination safety.

   c) To define generic technical safety aspects of nuclear desalination and to promote related technical activities including probabilistic safety analysis (PSA).

2. The safety and regulatory actions on nuclear desalination should be based on the following IAEA documents, which should be adopted by the national regulatory bodies.

   a) Safety fundamentals, the safety of nuclear installations, Safety Series No. 110 (1993).

   b) Relevant NUSS documents and guides on power reactors (Safety Series 50) and (Safety Series 35) on research reactors.

c) International basic safety standards for protection against ionizing radiation and for the safety of radiation sources.

3. It is vital for the nuclear desalination plant that the design, operation and the performance of an integrated nuclear desalination plant shall ensure protection of the product water against radioactive contamination.

4. Demonstration of licensability of a nuclear-desalination plant should be based on:

   a) Licensability in the country of origin.

   b) Design review of the plant.

5. Safety assessment and review by the importing country should be based on the following:

   a) Vendor's country licensing regulations and requirements, including codes, guides, standards, practices, etc.

   b) IAEA Safety Fundamentals, Basic Safety Standards, NUSS; research reactor safety series and related safety documents.

   c) Safety assessment and review shall be based on a combined deterministic and probabilistic approach.

6. Safety assessment and review can be undertaken in two stages; STAGE 1 in co-operation with the regulatory body of the country of origin based on its safety regulatory requirements which should be adopted by the importing country and STAGE 2 with the IAEA based on its safety documentation. In case of desalination reactors in the safety review stage, early participation in these activities is recommended by interested parties.

7. The regulatory, safety and environmental aspects identified for options demonstration of nuclear desalination to be reviewed by the authorities in co-operation with vendors according to a well defined plan with priorities and objectives. The safety analysis should include coupling and joint siting.

15. IMPLEMENTATION PROGRAMME

15.1. GENERAL

The introduction of nuclear power and nuclear technology in a country is a long, complicated and challenging process with three distinct phases:

- Conceptual preparatory phase.
- National infrastructure - preparing phase.
- Implementation phase.

A summary of activities in nuclear power projects is shown in Table 90. This chapter covers only project implementation. Thus it is assumed that all the conditions for launching a nuclear programme for the production of electricity and/or water are created, including:

- Infrastructure of the electricity grid.
- Adequate international framework.
- Qualified manpower.
- Industrial support.
- Financing.

Within the scope of a regional feasibility study, it is not possible to present a detailed project specific implementation programme. A specific project implementation programme in a given country depends on the national, political, social and economical structures of the country. The contents of this chapter present only some general guidelines for an implementation programme. The implementation of a specific programme has to consider the following factors:

A - <u>For the Nuclear Reactor:</u>

- Type of nuclear fuel (enriched or natural).
- Type of moderator and/or coolant.
- Political and economical issues involved in securing the supply of nuclear materials, components, and systems during the life time of the plant.
- Availability of alternative energy source(s), on or near the project site to secure the highest reliability for water production.

B - <u>For the Desalination Process:</u>

- Compatibility of the desalination process technology with the industrial base and the technical education system of the country.
- Availability of the materials needed for the construction of the main components.
- Plant lifetime, membrane replacement rate, and availability factor.
- Water production cost during the plant lifetime.
- Availability of alternative potable water source on or near the site.

Most of the above factors are not specified during this phase of the feasibility study. The following sections present an outline of a generic implementation programme. This generic programme can be detailed and tailored to be used for the implementation of either a demonstration or a full scale plant to be constructed on a specific site in a given country.

15.2 OUTLINE OF THE GENERIC IMPLEMENTATION PROGRAMME

The proposed implementation programme includes the following main tasks:

- Structure and assembly of the project management team.
- Specific site survey and investigation.

- Preparation of conceptual design/performance specifications.
- Bidding and contracting.
- Project and site infrastructure.
- Preparation and review of design and regulatory documents.
- Constructions and installations.
- Criticality and pre-operation tests.
- Commercial operation.

TABLE 90: SUMMARY OF ACTIVITIES IN NUCLEAR POWER PROJECTS

1. Project planning (pre-project, programme)	. National energy supply planning . Nuclear power programme planning . International agreements and arrangements . National participation planning . Site survey	. Power system planning . Development of legal and oriented activities . National infrastructure survey . Manpower development planning and implementation
2. Project implementation (pre-construction project-oriented activities).	. Feasibility study . Supply market survey . Preparation of specifications and invitation of bids . Bid evaluation . Financing arrangements . Plant conceptual design . Site and construction authorization (licensing)	. Site evaluation . Definition of contractual approach . Definition of codes and standards .Technology transfer arrangements . Procurement and assurance of fuel and fuel cycle services supply . Negotiation and finalization of contracts . Preparation of site infrastructure . Public information and public relations
3. Project implementation (management and engineering)	. Overall project management . Detailed design engineering . Preparation and review of equipment and plant specifications . Establishment of quality assurance policy . Supervision of manufacturing, construction and commissioning . Safeguards physical protection . Cost control . Development, review and implementation of safety and engineering procedures . Progress reporting	. Basic design engineering . Design reviews . Procurement of equipment and materials . Quality assurance and quality . Safety analysis . Emergency planning . Schedule planning and control . Planning and co-ordination of the training of operations personnel . Development of plant operation and maintenance manuals . Public information and public relations
4. Project implementation (manufacturing, construction and commissioning)	. Equipment and component manufacture . Site preparation . Plant equipment and systems installations . Commissioning and plant acceptance testing . Authorization (licensing) of plant operation and of plant operations staff . Quality assurance and quality control . Radiological protection and environmental surveillance . Fuel management at power plant . Licensing and regulatory surveillance	. Construction and commissioning management . Erection of buildings and structures . Plant component and system testing . Recruitment and training of plant operations personnel . Inspection and auditing . Plant operations and maintenance . Training and retraining . Safeguards and physical protection . Fuel and fuel cycle services . Waste management and disposal . Public information and public relations

15.3 TIME SCHEDULE

Figure 37 shows the schedule for a nuclear power plant covering the different phases of project implementation namely:

- Pre-project activities.
- Project implementation.
- Manufacturing.
- Plant construction.
- Commissioning up to commercial operation.

From this Figure it can be seen that the time period for a complete nuclear power plant project implementation, covering all of the above phases, is about 13 years. Out of this period the time for plant construction and commissioning is 6 years. This is the implementation time considered herein, assuming that the nuclear desalination plant will take the same time for manufacturing and construction as a nuclear power plant for producing electricity only.

Figure 38 shows a bar chart for implementing a nuclear power/desalination project, from the time the contract comes into force to the time of commissioning and commercial operation. The important dates in this time schedule are:

- Contracts coming into force (starting time).
- Beginning of site excavation work.
- Beginning of electro-mechanical work.
- Fuel loading and criticality tests.
- Power escalation and acceptance tests.
- Commissioning up to commercial operation.

15.4 STRUCTURE AND ASSEMBLY OF THE PROJECT MANAGEMENT

Due to the specific nature of the implementation of a "Nuclear Desalination Project", great care has to be given to the structure and assembly of the project management. The structure and assembly of such team is a country specific task since it is related to applicable legal, administrative and institutional rules and regulations. The proposed organization is based on one project general manager assisted by two deputy managers. The first is responsible for the technical aspects and the second is responsible for administrative aspects. The administrative deputy manager will act as the project general manager in the case of absence of the principal general manager. In case of long absence of the principal general manager, (more than 3 months) another general manager should be appointed by the owner of the project. Two senior staff members will assist the technical deputy manager; one for nuclear technology aspects and the other for the conventional plant (power generation/desalination). The administrative deputy manager may be assisted by two administrative staff members, the first is in charge of the legal and administrative aspects and the second is in charge of the budget, financial and accounting aspects. The proposed structure of the project management is shown in Figure 39. The project management team will act as the board of directors for the project until the completed plant is commercially operated and handed over to the operating authority.

The project management team should be given complete administrative and financial authority throughout the project implementation period. It is suggested that the highest ranking official in the owner's national authority act as the chairman of the board for the project implementation. The experience gained throughout the project implementation period can be further utilized for the implementation of other regional/inter-regional projects and/or for plant performance analysis tasks.

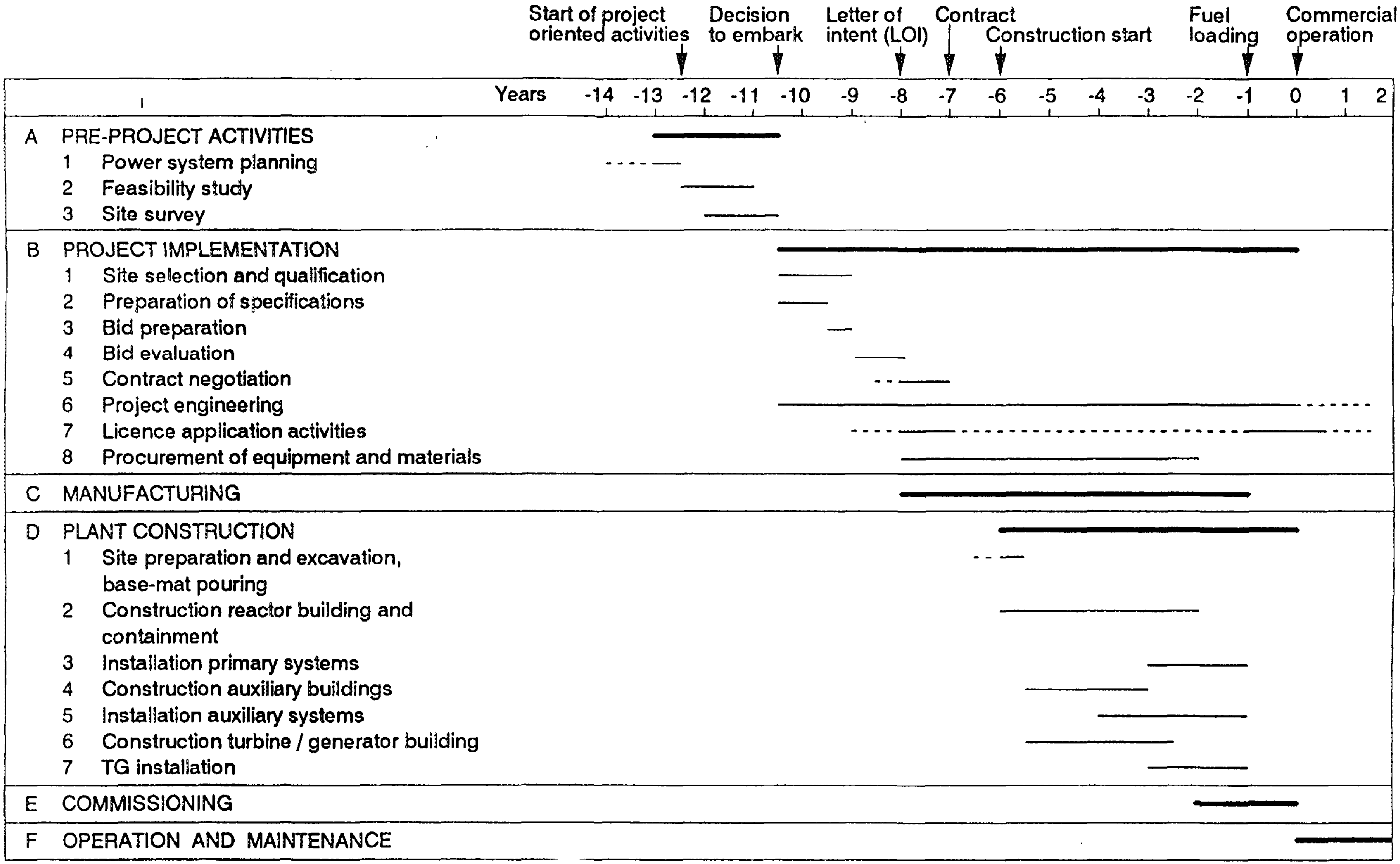


***Fig. 37:** Schedule for nuclear power plants complete implementation programme*

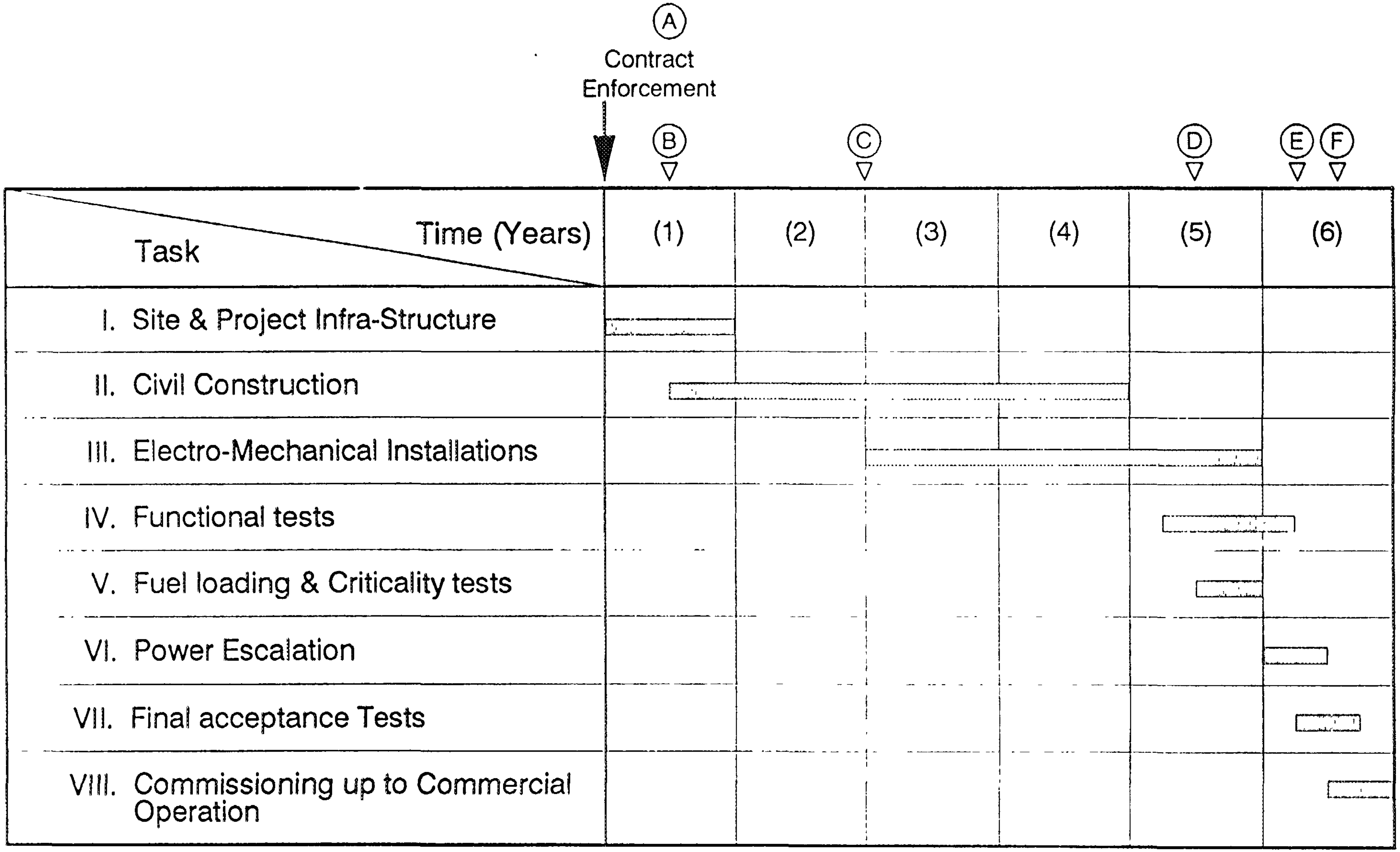


Fig. 38: *Time schedule for manufacture and construction program*

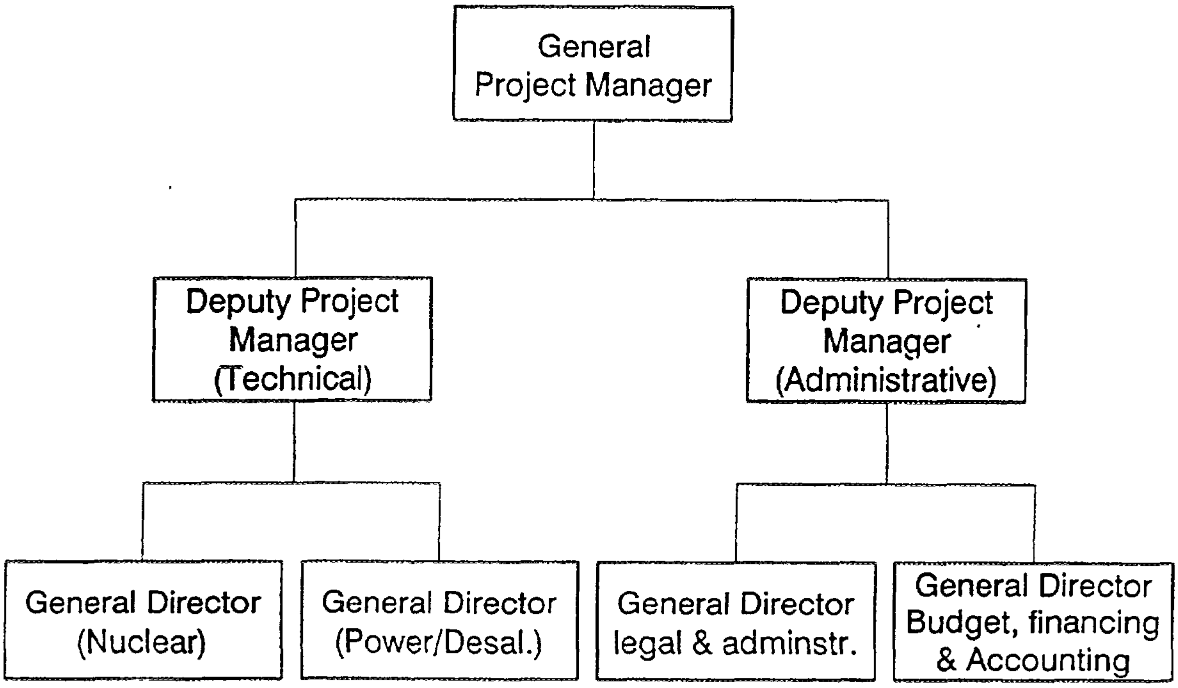


Fig. 39 *Proposed structure of project management*

15.5 SPECIFIC SITE SURVEY AND INVESTIGATIONS

In order to perform the task of conceptual design and performance specifications it is necessary to make some specific site survey and investigations covering the following:

- Location, geology, hydrology and meteorology.
- Population distribution within 50 km from projected plant site.
- Proximity to national electric transmission/distribution networks and potable water supplies.
- Availability and cost of construction materials.
- Availability of skilled labour.
- Legal/administrative/land rights.

15.6 CONCEPTUAL DESIGN AND PERFORMANCE SPECIFICATIONS

The main objective of this task is to compile and analyze all relevant data and information collected from the previous task (specific site survey and investigations) as well as demonstration facility programme and/or implementation and findings of the regional feasibility study and its references. This is to develop the conceptual design of the full scale nuclear powered desalination plant and performance specifications, which will be included in the Bid Invitation Specification (BIS) documents, together with the relevant site specific data and general conditions.

The work on this task can also serve the purpose of preparing relevant safety analysis regulatory documents (e.g. Site Evaluation and Preliminary Safety Analysis Reports). In case that the maximization of local participation is a national requirement, review and analysis of engineering and industrial market surveys may be included in this task or done in a separate task when justified.

15.7 BIDDING AND CONTRACTING

Depending on the national method adopted for project implementation (Turnkey, Split or Multiple package), the BIS documents have to be carefully prepared in order to assure the maximum competition between suppliers, and a well defined assignment of responsibility for the whole project. Data collected and analyzed in the previous tasks should be used as the basis for the preparation of the BIS documents for the Architect Engineer, Nuclear Power Reactors and Desalination Units suppliers. Depending on the political/financial agreements between technology supplier and receiver countries bidding can be either international, limited or direct. In this section, only the two cases of international and limited bidding procedures, are considered

15.7.1 International Bidding

This is the most open method for bidding, in which BIS documents are issued for international bidding. BIS documents can be issued for a turnkey or split package project. It is recommended that the bid is requested to be presented in two envelopes, namely:

<u>Envelope A: Technical Proposal</u>

This includes the technical data and specifications for major project items, together with the vendor's past experience for the project, or for one or more of its packages, according to the conceptual design, performance specifications and general conditions of the BIS documents. It should also include the vendor's past experience in the most relevant reference plant, of comparable size to that of the project.

<u>Envelope B: Prices and Financial Proposal</u>

This includes the itemized prices for the whole project, or for one or more of its packages, together with the proposed financial plans. In most cases the buyer requests the presentation of a bid bond amounting to 1-2% of the total project or package(s) cost. In this case it is suggested to present a letter from the bidder indicating that such a bid bond is included in envelope B. This allows the prices of the bids to remain unknown to the other competitors until the date of opening envelope B.

A pre-bid meeting is recommended in the interval between the issue of BIS document and the deadline for opening envelope A. The purpose of this meeting is to clarify the buyers requirements included in the BIS documents. Before the deadline of presenting the complete bid (two envelopes A&B) and opening of the first envelope (envelope A), the project general manager should form a committee for receiving the bid documents and opening of the first envelope (envelope A) in the presence of all bidders and/or their official representatives.

After all bids are received and the technical proposal envelope (envelope A) is opened, the project general manager should form a number of specialized technical groups for the technical evaluation and comparison of the bids. At this stage, the buyer could communicate with the vendor (bidder), through its local representative, to clarify the technical aspects, that can help in the fair evaluation of bids and their compliance with the BIS documents. After all bids are technically evaluated and ranked accordingly, the vendors are notified with the date of opening the second envelope (envelope B). Before this date, the vendor could present any adjustments to the prices presented in envelope B. These adjustments can be presented in a third envelope (envelope C). After the second and/or third envelopes are opened and the received bids are re-ranked accordingly, the successful bidder (No. 1) is selected and notified by a letter of intent.

The successful bidder is asked to prepare a draft contract to be negotiated with the buyer (owner). On the other hand, the project general manager (representing the buyer) will form a contracting committee to prepare a draft of the buyer's version of the contract. The vendor's and buyer's versions of the contract are negotiated until a final version of the contract is reached. The final version of the contract should be reviewed from the legal, the financial and administrative authorities in both the vendor and buyer countries. After the contract documents are finalized and approved and the proper agreements to secure the supply of fresh nuclear fuel and the storage or disposal of depleted (burnt) nuclear fuel are signed, the contract documents are signed and officially declared.

15.7.2. Limited Bidding

Due to the special nature of nuclear technology it may be appropriate to limit the call for tenders to the supplier countries that have nuclear technology transfer agreements with the buyer countries. In this case the tender documents are preparea in the same way as for the case of international tendering, however instead of the wide advertising for calling the bidders, the bid documents are either sent free of charge to the consulates or commercial representatives of selected vendor countries or a limited call for tenders is advertised to those selected vendor countries. The tender process can be either a one envelope process or a two envelopes process like the one described before. The main disadvantage of the one envelope process is the declaration of the prices at the time of opening the technical envelopes of the bidders. These declared prices may not be for the same scope of supply and the same fulfillment for the technical specifications of the project. This may lead to some complaints and legal disputes if the vendor with the lowest declared price is not selected. The technical, economic and financial evaluation of the tenders for the case of limited tendering is easier than international tendering, due to the smaller number of tenders received. The procedure for contracting after the selection of the best offer can be the same as for international tendering. One of the important requirements for nuclear power projects for electricity generation and/or desalination of seawater is the regulatory and licensing requirements, and associated documents such as:

- Site Evaluation Report.
- Preliminary Safety Analysis Report (PSAR).
- Final Safety Analysis Report (FSAR).

The responsibility for providing the data and preparation and editing of these documents according to licensing procedures should be carefully spelled out in the final version of the contract with the Architect Engineer and/or the Vendor.

15.8 PROJECT AND SITE INFRASTRUCTURE

After the contract with the successful bidder is officially signed and the budget for the project is allocated by the financial institutes, the contract will come into force usually after the fulfillment of the following:

- The vendor receiving the contract specified down payment.
- The buyer receiving the guarantee for the down payment and the guarantee for proper project implementation until the stage of commercial operation.
- The buyer issuing a preliminary certificate indicating the reference starting date for the contract coming into force.

Usually the site preparation and the supply with the proper electric energy and fresh water sources, necessary for the construction period, and for the successful operation of the project during its lifetime, is the responsibility of the buyer country. Therefore it is necessary for the successful implementation of the project, that the projected site should be properly selected, prepared and supplied with adequate electric energy and fresh water supplies by the time specified in the contract. The failure to fulfill the site preparation requirement may cause some delays and extra costs for the project. This delay may have severe economical consequences, depending on the economic utilization of the produced electric power and/or desalinated water. It is suggested that the preparation of the prospect site should take place well before the contract enforcement date to avoid such delays and consequences. Alternative plans should also exist for the development of the site area using other energy sources, if the nuclear option is suddenly ruled out due to political, public acceptance, or ecological reasons. The main services needed for the preparation of a particular site for a seawater desalination project using nuclear energy include:

- Fresh and potable water supply for use during the construction period and possibly for plant operation and maintenance after commercial operation.
- Electric power source to supply the construction site with needed energy for the construction period (4-6 years) and for the operation and maintenance of the completed plant during its projected lifetime (30 years).
- Access roads to facilitate access of personnel and construction equipment carrying the heaviest part expected during the construction period.
- Temporary living facilities for site management, plant construction and erection personnel. Usually it is the contractors responsibility to build and erect the temporary and/or permanent facilities needed during the construction period. It is the owners responsibility to secure the electrical power and fresh water supplies needed for the construction period. The cost of consumed energy and fresh water is usually paid by the contractor according to the terms of the contract.

15.9 PREPARATION & REVIEW OF DESIGN AND REGULATORY DOCUMENTS

After the contract has come into force, the main contractor will prepare the design documents, together with the safety analysis reports necessary to obtain the construction and operating permits. The owner has to review these documents and present them to the national regulatory body. When a site evaluation report is required for issuing a construction permit, it is the owner's responsibility to prepare the site characteristics data required by the National Regulatory Authority. Design features that are site related have to be prepared by the reactor's supplier through the main contractor, if different than the reactor supplier. The main contractor, together with the reactor supplier, should have the responsibility of preparing the preliminary and final safety analysis reports when necessary, of completing the construction of the reactor plant, nuclear fuel loading in the reactor and reaching the stage of full commercial operation. Emphasis has to be put on the quality of produced water to make sure that the radiation dose in case of the most severe reactor accidents is within the ICRP prescribed values.

15.10 CONSTRUCTION AND INSTALLATION

This is the main task of the whole project. It starts with the first borings for soil investigations, necessary for laying the main buildings foundations, and ends with fuel loading and criticality experiments.

The following main points should be considered during the construction and installation task:

- Well defined share of tasks and responsibility between the main contractor, the owner and the regulatory body to avoid unnecessary delays in the project schedule.
- Complete and clear documentation of the as-built facility and identification of main deviations from design documentation.
- To make necessary design configurations, in order to facilitate the maintenance of the building and equipment during the life time of the plant.

15.11 CRITICALITY & PRE-OPERATIONAL TESTS AND EXPERIMENTS

After the constructions/installations are completed and the regulatory body has approved loading, the criticality experiments and tests start. During criticality start-up, reactor control is performed by the start-up loop, which receives its primary signals from a number of neutron detecting elements. These neutron detectors produce electrical signals which are indicative of the actual power level of the reactor and/or the rate of change of this power level.

The control rods are moved outside the core either manually or automatically. Movement of these control rods is in such a manner to increase the rate of fission and, hence, the neutron population and the reactor power. The main emphasis during the criticality experiments is to tune-up the instrumentation and controls of the start-up loop and to test the safety control rods function. After the reactor has reached criticality, the power increase experiments are performed, to test the operating loop of the reactor and desalination plant control system. These tests are performed and carefully documented to serve as the benchmark for future performance tests during the operation and maintenance of the plant throughout its lifetime.

15.12 COMMERCIAL OPERATION

After all power escalation and final acceptance performance tests are performed, well documented, and officially approved by the owner's representative (e.g. the project general manager or the owner's appointed plant general manager), the plant is officially handed over to the owner.

During the guarantee period stated in the contract, the main contractor together with, the reactor/nuclear power plant vendor(s), and the desalination plant vendor(s), should maintain an active presence during that period of time, and should provide all the guidance, assistance and technical support that is required to assure satisfactory operation at all times.

An important factor for the successful operation and maintenance of the overall plant is the manpower development programs which guarantee the maximum transfer of technology to the owner's personnel taking all human and social factors into consideration.

16. INSTITUTIONAL ASPECTS

16.1 GENERAL

The introduction of nuclear power for electricity generation and for seawater desalination requires new infrastructure requirements and involves national and regional commitments on a long-term basis. These include on-going political and institutional policy commitments and commitment over a long period of time of substantial manpower and financial resources. Hence the institutional aspects of a large scale energy and water production programme must be clearly understood and addressed for successful programme implementation, and clear policy commitments must be established to ensure continuity of the programme. In many cases these institutional and resource commitments may not be practical on a national basis. Regional co-ordination and co-operation can provide a framework within which the necessary infrastructure can be established, and within which the institutional and resource commitments necessary to ensure a successful programme can be made.

The purpose of this chapter is to address the various institutional issues which should be considered. These are addressed under the general categories:

- Planning and regional considerations.
- Infrastructure and national participation.
- Financing.
- Safety and regulatory aspects.
- Safeguards.
- Public acceptance.

In some cases, these issues have been introduced and addressed in more detail in earlier chapters. Nevertheless, they have been included in summary form in this chapter in order to provide an integrated overview of the full scope of institutional issues which must be addressed.

16.2 PLANNING AND REGIONAL CONSIDERATIONS

16.2.1 Long Term Energy and Water Supply Development

Large scale desalination of seawater requires detailed assessment on a long term basis of resources and of demand/supply, taking into consideration relevant aspects and assessing them in comparison with other long term possible water supply options. Thus, seawater desalination projects cannot be justified only by a generic study comparing the water costs at the outlet of the various means of potable water production. Such a comparison only provides orders of magnitude for the main parameters, which could be very helpful for the planner, but are not sufficient for investment decisions.

On the regional level, the development of a desalination programme as part of an overall energy and water programme should be justified on an economic basis by comparison with other water supply options together with the necessary water transport and distribution infrastructure and the associated energy requirements. If nuclear power is chosen as the energy source for seawater desalination, then it is essential to have a long term national nuclear energy programme and the policy and strategy for implementing it. The special features of nuclear energy require the establishment of organizational structures, highly competent personnel, national infrastructures, and substantial financial resources. The deployment of significant regional resources is only possible if there is a firm commitment by the governments to the programme. A single nuclear power reactor not integrated into a nuclear programme is an expensive proposition. However, it could be justified for demonstration purposes, if the associated costs are shared by the international community.

16.2.2 National Organizations involved in the Implementation and Operation of Nuclear Desalination Plants

The initiation and formulation of a nuclear desalination programme, as well as the subsequent implementation of nuclear desalination projects, require from the institutional point of view adequate organizational structures for the management of required activities, at the governmental level, as well as in the utilities, industry, research and development and educational institutes involved.

This organization or project group will have the main task of defining the nuclear desalination programme in policy, scope, size, schedule, budget, manpower requirements and the assessment of available domestic resources and capabilities for participation for its implementation.

It could be initially a part or a department of a government ministry or organization, with a special board composed of selected high level members which will have the national organization to be in charge of the co-ordination of the nuclear desalination programme. It can be initially formed by:

- The atomic energy commission or the authority concerned with nuclear activities in the country.
- The ministry or authority in charge of water production, storage, transport and distribution.
- The ministry concerned with the energy resources and development.

At the beginning only a small organization with relatively few but highly qualified professionals working as a project group will be required. The project implementation phase starts when the decision is reached to proceed with planning of a specific nuclear desalination project. The organizational structure requirements for the management of the activities during this phase depend to a large extent on the contractual approach adopted for project implementation. The owner's organization has the overall responsibility for the project and the functions of supervision and control of all activities, as well as the review and approval of the work to be performed, even if the lead responsibility is delegated to suppliers.

For small desalination plants (a few hundreds or thousand of m^3/d capacity), which include their own on-site energy supply sources (heat or electricity or both), a single owner-operator, possibly the organization responsible for water supply (including the supply of energy), seems to be the best solution.

A contiguous plant, where the nuclear power plant is co-located with the desalination plant, provides the opportunity to share facilities which might otherwise have to be duplicated for each plant if they were located separately, and could lead to a reduction in overall energy consumption and costs. In order to achieve this, it has to be approached from the standpoint of an integrated facility, and to have an integrated facility management. Additional benefit derived from the integrated management include the consideration of the power and desalination facility into a single plant thereby reducing maintenance, management and construction costs. Such cost saving include the construction of only a single intake and outfall structure. It has to be mentioned that the costs involved in the water storage and transportation to the consumer has not been considered in the cost comparison in Chapter 11.

16.2.3 Assurance of Reliable Supply

Reliable supply must be assured under all conceivable conditions. Assurance of reliable supply also applies to industrial use because, without water, production would come to a standstill. Reliable supply of water to the population and industrial use should be ensured. No industrial installation, whether it is a desalination plant or a power plant, can have 100% availability and reliability. There are always planned as well as unplanned outages and thus measures must be taken to provide for uninterrupted supply of the minimum requirements at all times.

From the point of view of reliability of supply, the availability of unpolluted feed water (seawater) is also essential. Pollution of the sea through major oil spills constitutes a risk to be taken into account. Diversification of potable water sources, with several smaller desalination plants spread out along the coast instead of one large centralized facility to serve the market, is an approach which must be considered. Water costs will undoubtedly be higher, but the risk of supply interruption may be reduced.

The desalination plant can only function if it is supplied with energy, so reliable energy supply must also be assured. Generating reserve capacity and redundancy are possible measures, because energy storage is not practical.

Uninterrupted supply of electricity is relatively easy to assure when the desalination plant is connected to a reliable grid, which includes adequate reserve capacity and redundancy. In practice, electrical grids operate with outage probabilities well below 1%. Should the grid be not sufficiently reliable, on-site standby capacity will be needed to provide essential services during short grid outages, which would practically not affect potable water production and supply. Without grid interconnection, reliable electricity supply can only be assured by having adequate standby reserve capacity and redundancy to allow for planned as well as unplanned outages, which might be quite long. Reliable supply of heat can only be achieved by having adequate on-site reserve capacity and redundancy. In this respect, modular designs are an asset.

16.2.4 Regional Considerations on Nuclear Fuel Cycle

For the North African countries, the supply of the nuclear desalination plant and the supply of nuclear fuel elements have to be considered simultaneously. An even more careful consideration must be given to the fuel supply. A failure in supplying the plant with fuel would not only mean being left with an unproductive investment, but would also affect negatively the water supply.

One of the most important factors that can influence the choice of reactor type for a nuclear desalination plant is the adoption of the fuel cycle and related services and activities. It is likely that considerations of national or regional strategy, including reactor type, waste management approach, environmental impact, and public acceptance will play an important role in deciding a fuel cycle policy.

For the long term supply, the contribution of multinational fuel cycle arrangements to assure supply, e.g. multinational facilities or regional nuclear fuel cycle centers was outlined by many experts. The first charge of fuel and the options for future refueling can be included in the scope of supply of the nuclear desalination plant. To ensure the long term supply of this essential service, the development of domestic capabilities seems to be feasible only for a country with a reasonable sized nuclear desalination programme. If this is not the case, the establishment of a regional fuel cycle center serving all the NACs may be an appropriate solution.

The different tasks, functions and steps in the nuclear fuel cycle may also be geographically distributed according to the domestic resources potentials and capabilities of each country.

A regional approach to the nuclear fuel cycle would yield the following advantages:

- Improve the economics of the whole fuel cycle as compared to the development of individual national capabilities.
- Improve the nuclear safety on a regional basis by reducing the environmental risk associated with a multi-disposal option.
- Concentrate the NACs' efforts on activities for which they have a potential.

16.3 INFRASTRUCTURE AND NATIONAL PARTICIPATION

16.3.1 Project Planning and Implementation

Seawater desalination is an energy intensive process, and a large scale desalination complex involves both energy production and water purification technologies. Each of these technologies has its own established project planning and implementation process. Each will need to follow the usual process of completing all successive necessary steps of overall planning, establishment of feasibility, safety assessment, siting study and site qualification, acquisition (bidding and contracting), construction, erection, commissioning, and training to ensure sufficient and qualified personnel.

If a nuclear reactor is chosen as the energy source, then the time needed to complete the acquisition, licensing, construction and commissioning of the reactor would need to be carefully integrated into the overall planning structure.

16.3.2 Regional QA/QC Considerations

A pre-requisite for manufacturing nuclear and desalination equipment and systems in the region is a comprehensive and compatible QA/QC regime. The need for substantial indigenous manufacture in a nuclear desalination plant means, therefore, that the NACs should now start developing specific QA/QC codes of practice for the region. These should be acceptable, and if possible, mandatory within the region. It should be based on internationally accepted best practice. A suitable framework is the ISO-9000 series and the NUSS quality documents. The implementation of a regional QA/QC policy should be backed up by a series of regional laboratories to ensure inspection standards are maintained and are uniform throughout the area.

It is recommended to establish a Regional Quality committee to undertake this responsibility as well as harmonization of quality technology, systems and culture in the region.

16.3.3 Manpower Development Programme

Some of the major factors affecting safety and reliability of nuclear power desalination units is the qualified manpower for construction, operation and maintenance. Any country embarking on a nuclear power desalination programme must prepare a comprehensive manpower development programme. This programme must be consistent with national participation policies. The overall manpower requirement for the different project phases of nuclear power is presented in Ref. [63].

The national or regional nuclear desalination manpower requirements depends on:

- Nuclear desalination power programme.
- Percentage of local participation.
- Constraints and limitations.
- Labour quality and availability.

It should be emphasized that high technology projects such as nuclear desalination require a realistic assessment of the organizations involved, as well as educational and industrial capabilities in order to increase the quality and quantity of manpower in different required disciplines. The gap between requirements and capabilities can be closed through good planning from the early stages of the project.

16.3.4 Assessment of Local Capabilities

In a free market economy, countries with similar economic structures are grouped to make the best use of their local capabilities. The ultimate goal in this project is to have self sufficiency and integration to acquire, master and develop the technology of water desalination using nuclear energy.

The five NACs have an excellent opportunity for the maximization of local participation in the implementation of a nuclear desalination programme. In order to achieve this co-operation scheme, bilateral agreements to perform regional assessment of local capabilities have to be undertaken, these local capabilities should include:

- Industrial capabilities for the manufacturing of the various components of a standardized nuclear desalination plant.
- Manpower development programmes needed for management and implementation of nuclear desalination project.

16.4 FINANCING

Seawater desalination plants, water storage, transport and distribution systems and energy generating plants, in particular nuclear reactors, are all capital intensive installations. Depending on its size, a seawater desalination plant will require a capital investment for water storage, transport and distribution systems, which could be of the same order of magnitude as those for the desalination plant.

Several financing options and schemes were discussed in Chapter 12. The discussions indicated that the NACs would have to depend on themselves for providing the necessary funds for any future nuclear project, desalination or otherwise. In this regard, the establishment of a Regional Drought Fund to finance water development projects, should be seriously considered.

It is also important to adjust the water and electricity tariffs by the governments to reflect the real costs of these commodities. Only in this way will the project executing utility achieve the sound financial strength needed to finance from its own resources or be considered creditworthy by banks.

16.5 SAFETY AND REGULATORY ASPECTS

The safety and regulation of nuclear power plants, with emphasis on their use as energy sources for seawater desalination, has been discussed in Chapter 14. It is clear that the creation of a successful safety and regulatory approach and programme is primarily an institutional issue. It is recognized that nuclear safety regulation is a national obligation which cannot be assumed by a regional body. It requires the establishment in each country of a comprehensive infrastructure capable of ensuring that all applicable international codes, conventions and requirements have been adhered to.

The North African countries have many things in common, one of which is the lack of a currently existing power reactor. This provides the opportunity for a strong regional approach in the development of regulatory activities. The creation of a regional North African Safety Advisory Group (NASAG) could facilitate the development of a common institutional framework which would serve as a model for various national bodies. It could undertake joint studies aimed at reviewing existing legislative frame work, regulatory infrastructure and safety culture attitudes, with a view towards formulating a work plan to strengthen all nuclear safety related activities based on fundamental safety principles as applied uniformly across the region. Further, the NASAG could define generic technical safety aspects of nuclear desalination and undertake appropriate technical work, including probabilistic safety analyses, in these areas. By harmonizing regulatory and safety activities among the North African countries, it should be possible in most respects to formulate a common regional approach to nuclear desalination safety.

16.6 SAFEGUARDS AND NON-PROLIFERATION

International concerns regarding assurance of the use of nuclear energy for exclusively peaceful purposes are related only to the nuclear reactor and its fuel. The end use of the energy produced, i.e. desalination of seawater or any other use, is in itself irrelevant.

For these reasons, a country will obtain nuclear technology, nuclear reactors, nuclear fuels, materials and equipment from a foreign supplier only if it can provide adequate evidence of their exclusively peaceful uses, to the full satisfaction of the potential supplier and the international community. This situation prevails now and will also be the case for the foreseeable future.

Other concerns regarding nuclear reactors, such as physical protection or third party liability, also need to be resolved through governmental commitments, irrespective of the end use of the energy produced.

16.7 PUBLIC ACCEPTANCE

Experience shows that public and political acceptance of nuclear energy strongly depends on the perception of the risks incurred and of the benefits obtained from using this energy source. Opponents tend to exaggerate risks and ignore benefits, and this view is often transmitted to the public at large by the media. Experience also shows that in addition to the overall perception of nuclear risks and benefits, the public is influenced by the so-called NIMBY (Not In My Back Yard) syndrome. This would negatively affect the acceptance of a site for a nuclear reactor close to population centers and would favor more distant sites perceived as being beyond "my back yard".

The advanced reactor concepts currently being proposed by the nuclear industry share the common goal of achieving increased safety levels. This is expected to improve public acceptance of nuclear energy, as well as to alleviate to some extent growing public concerns regarding environmental pollution and climate change caused by emissions from the burning of fossil fuels. Obviously, to gain public acceptance for nuclear desalination, it will have to be demonstrated credibly that there is minimal risk of radioactive contamination of the product water.

A positive aspect is that water in desert cultures is synonymous with life. The use of nuclear energy to supply water and to develop desert regions, will be highly welcomed if safety, environmental impacts and economics are ensured. Selection of proven reactors based on recent developments in safety and safety fundamentals is essential in this regard.

The concept of regional developments and public participation from the early stage is recommended. The experience in France in this respect is valuable. At some time a public acceptance committee in the NACs should be created to undertake careful planning for public acceptance in co-operation with mass media in the region.

17. CONCLUSIONS AND RECOMMENDATIONS

The present regional feasibility study is a promising start to promote the sharing of efforts and ultimately also the benefits among the North African Countries. During the course of the study lessons have been learned. It has been found that there are problems and difficulties in co-ordination, communications, control, assignment of responsibilities and performance of tasks on schedule. Nevertheless, it has also been found that there are ways to solve the problems and it is possible to reach workable compromises. As a result, the study was concluded successfully with the following conclusions and recommendations.

17.1 CONCLUSIONS

1. Despite the anticipated success of the NACs in reducing the average annual population growth rate from about 2.6%, in the period 1950 - 1990, to about 1.8% in the period 1990 - 2025, the NACs' population might reach 220 million people in the year 2025. This, together with the increasing urbanization, developmental needs, and the rising living standards, will increase the demand for both electricity and water.

2. All five NACs lie within the temperate zone and the bioclimate varies from arid to extremely arid. Drought years are common. Rainfall in most parts of the region is marginal and insufficient to cover current demand for fresh water. Apart from the River Nile in Egypt, no significant surface water resources exist in the Region. Therefore, groundwater resources play an important role in providing regional needs for fresh water. However, most of these resources are fossil and available at great depth. The estimated overall regional water deficit, by the year 2025, is 40 Mm^3/d. Seawater desalination could play an important role in closing this gap.

3. The only significant indigenous primary energy resources in the Region are crude oil, natural gas and hydraulic energy. Unless new discoveries are made, oil and gas will be depleted in the next century. Hydraulic energy is nearly fully utilized. The average annual growth rate of the required installed capacities in the Region is estimated to be 5%. By the year 2025, the required installed capacity would be more than 100 GW(e), i.e. more than five times the regional installed capacity of 1990.

4. Nuclear power could play an important role in meeting the expanding regional needs for energy that can be supplied to the grid in the form of electricity, or to desalination plants as heat and/or electricity. There are no technical impediments to the use of nuclear reactors for the supply of energy to desalination plants.

5. Based on the selected energy source/desalination process combination for five regional sites, it was found that costs of desalted water for the most economic fossil and nuclear driven desalination processes were in the same range. The most economic desalination process seems to be contiguous RO plants with preheated feedwater. Higher fuel prices and/or lower interest rates will make the nuclear option more economic.

6. There are indications that important regional manufacturing capabilities exist. However, for the NACs to achieve the goal of self sufficiency, adequate supply of trained manpower, additional and improved manufacturing facilities, financial resources and a strong NACs government commitment to a nuclear power programme are necessary.

7. Financing nuclear power projects in the NACs with the current approaches might be difficult. In particular, providing the foreign component of investment from

international markets could be problematic. Therefore, the Region will have to depend on its own resources.

8. Nuclear safety and environmental considerations in nuclear desalination are mainly those arising from the use of nuclear reactors as energy sources. In addition, the desalination plant may have an environmental impact associated with concentrate discharge.

9. The NACs can obtain nuclear technology, nuclear reactors, nuclear fuel, materials and equipment from foreign supplier only if they can provide adequate evidence of their exclusively peaceful uses, to the full satisfaction of the potential supplier and the international community.

17.2 RECOMMENDATIONS

The results of the present regional feasibility study have been positive, in general, and the efforts have generated an increasing level of co-operation within the Region. A large number of issues have been identified. These should be addressed, on both a regional and national basis, to capitalize on the work carried out to date. In this regard the following recommendations are made:

1. Establish a small group of multi-disciplinary NACs' experts to define the necessary steps and tasks, based on the results of the present study including their costs, needed to start a second phase of this study, namely "The Impact of Site Specific Aspects on the Use of Nuclear Power for Seawater Desalination". This second phase study would include, but not be limited to, the following:

   - Narrow down the number of reference sites, possibly to the three identified joint sites (or at least one of them).
   - Select the most promising systems from this study.
   - Ensure more reliable data for water demand and deficit.
   - Define the infrastructure requirements for fossil and nuclear options at the selected site(s).
   - Identify the scope of regional participation.

2. Establish a Regional Water Commission whose primary role would be to create, maintain and update a reliable regional data base on the existing fresh water resources, future plans for seawater desalination development, potable water supply, demand and deficit.

3. Acquire the necessary skills within the Region to develop modeling capabilities needed for analysis of various reactor/desalination systems.

4. Establish a North African Safety Advisory Group (NASAG) to give advice on nuclear safety issues related to nuclear desalination. NASAG could also set up the basic safety criteria for the Region, and review and harmonize existing legislative and regulatory framework in the Region.

5. Establish a Regional body to maintain and update a data base of manufacturing capabilities in the Region. A detailed and in depth regional study on the manufacturing capabilities could be the first task.

6. Consider the establishment of a Regional Drought Fund for the supply of the necessary funds, and the adoption of investment priority policies to carry out a "nuclear desalination" programme.

ANNEX I

COUPLING BETWEEN SELECTED ENERGY SOURCES AND DESALINATION PROCESSES

FOR TRIPOLI, LIBYA (720,000 m^3/d)

(MATRIX AND SPREADSHEETS)

TABLE I.1: Tripoli, Libya - 720,000 m^3/d

Primary Energy	Energy Cycle	Scheme	MED	Stand Alone RO	Contiguous RO	Hybrid
Nuclear	Steam Power Plant	CANDU 3 NP-300	I Libya-3 Libya-1	II-A Libya-3 Libya-1	II-B Libya-3 Libya-1	III Libya-4 Libya-2
	Power Brayton Cycle	GT-MHR			IV-B Libya-5	
	Heat Only Steam Cycle	AST-500	V-a Libya-9			
Fossil	Steam Power Plant	gas	VI-c Libya-6	VII-A Libya-6	VII-B Libya-6	
	Gas Turbine	oil/gas				XI Libya-7
	Gas Turbine Combined Cycle	oil/gas				XIV Libya-8

* Data given in this table are only indicative

LIBYA.XLS

	A	B	C	D	E	F	G	H	I	J	K
1		IAEA DESALINATION COST ANALYSIS - REGIONAL STUDY							LIBYA.XLS		
2		LIBYA SITE WITH WHO WATER QUALITY STANDARD							29-Sep-94		
3		(All values in U.S. Jan.94 $)									
4											
5		SPREADSHEET ORGANIZATION:	START ROW #	END ROW #							
6											
7		PLANT CHARACTERISTICS	17	38							
8		PERFORMANCE INPUT DATA	40	101							
9		COST INPUT DATA	103	140							
10		ECONOMIC PARAMETER INPUT DATA	142	157							
11		PERFORMANCE CALCULATIONS	159	212							
12		COST CALCULATIONS	214	251							
13		ECONOMIC EVALUATIONS	253	395							
14		SUMMARY	396	524							
15	i	(i = input data)									
16		PLANT AND SITE CHARACTERISTICS:									
17											
18	i	CASE	Libya-1	Libya-2	Libya-3	Libya-4	Libya-5	Libya-6	Libya-7	Libya-8	Libya-9
19	i	ASSUMED LOCATION	TRIPOLI	TRIPOLI	TRIPOLI	TRIPOLI	TRIPOLI	TRIPOLI	TRIPOLI	TRIPOLI	TRIPOLI
20	i	WATER DEMAND, CU.M/D	720000	720000	720000	720000	720000	720000	720000	720000	720000
21	i	PLANT TYPE	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	FOSSIL	FOSSIL	FOSSIL	NUCLEAR
22	i	PRODUCT	HEAT & POWER	HEAT & POWER	HEAT & POWER	HEAT & POWER	POWER ONLY	HEAT & POWER	HEAT & POWER	HEAT & POWER	HEAT ONLY
23	i	REFERENCE TO GENERIC CASES	I, II	III	I, II	III	IV B	VI, VII	XI	XIV	V
24	i	FUEL TYPE	UO2	UO2	nat. UO2	nat. UO2	UCO	GAS	GAS	GAS	UO2
25	i	REACTOR OR FOSSIL PLANT TYPE	PWR(NP-300)	PWR(NP-300)	CANDU-3	CANDU-3	GT-MHR	STEAM TURBINE	GAS TURBINE	COMBINED CYCLE	AST-500
26	i	SIZE CATEGORY	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM
27	i	WATER PLANT TYPE	MED OR RO	MED/RO HYBRID	MED OR RO	MED/RO HYBRID	RO	MED OR RO	MED/RO HYBRID	MED/RO HYBRID	MED
28	i	SELECTED UNIT NET OUTPUT, MWe (MWt)	300	300	450	450	287	600	175	450	500
29	i	TOTAL NET OUTPUT, MWe (MWt)	600	300	450	450	287	600	350	450	1000
30	i	SERVICE YEAR	2005	2005	2005	2005	2005	2005	2005	2005	2005
31	i	CURRENCY REFERENCE YEAR	1994	1994	1994	1994	1994	1994	1994	1994	1994
32	i	SALEABLE POWER	YES	YES	YES	YES	YES	YES	YES	YES	NO
33	i	ASSUMED AVG COOLING WATER TEMP, C	21	21	21	21	21	21	21	21	21
34	i	MED DESIGN COOLING WATER TEMP, C	27	27	27	27	27	27	27	27	27
35	i	RO DESIGN COOLING WATER TEMP, C	18	18	18	18	18	18	18	18	18
36	i	CONTIGUOUS RO PREHEAT TEMPERATURE, C	18	32	18	32	32	18	32	32	N/A
37	i	SEAWATER TOTAL DISSOLVED SOLIDS, PPM	38500	38500	38500	38500	38500	38500	38500	38500	38500
38	i	PRODUCT DRINKING WATER STANDARD	WHO	WHO	WHO	WHO	WHO	WHO	WHO	WHO	WHO
39											
40		PERFORMANCE INPUT DATA									
41		BASE POWER PLANT PERFORMANCE DATA:									
42	i	NET THERMAL EFFICIENCY, %	31.6	31.6	29.7	29.7	47.8	40.0	33.0	50.0	N/A
43	i	BOILER EFFICIENCY, %	N/A	N/A	N/A	N/A	N/A	0.92	0.92	0.92	N/A
44	i	MAIN STEAM TEMPERATURE, C	293	293	260	260	N/A	538	N/A	427	N/A
45	i	MAIN STEAM PRESSURE, BAR	77.8	77.8	46.9	46.9	N/A	163.0	N/A	81.6	N/A

	B	C	D	E	F	G	H	I	J	K
46	CONDENSER RANGE, C	8	8	8	8	N/A	8	N/A	8	N/A
47	CONDENSER COOLING WTR PUMP HEAD, BAR	1.7	1.7	1.7	1.7	N/A	1.7	N/A	1.7	N/A
48	CONDENSER COOLING WTR PUMP EFFICIENCY	0.9	0.9	0.9	0.9	N/A	0.9	N/A	0.9	N/A
49	CONDENSING TEMPERATURE, C	37	37	37	37	N/A	37	N/A	37	N/A
50	PLANNED OUTAGE RATE	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.110
51	UNPLANNED OUTAGE RATE	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.050
52										
53	DUAL-PURPOSE PLT PERFORMANCE DATA:									
54	CONDENSING TEMPERATURE, C	88.5	62.5	99 5	53 5	N/A	110.5	N/A	67.5	N/A
55	INTERMEDIATE LOOP FLASH STM TEMP, C	82	56	93	47	N/A	N/A	N/A	N/A	114
56	INTERMEDIATE LOOP COND. RTRN TEMP, C	80	54	91	45	N/A	N/A	N/A	N/A	112
57	INTERMEDIATE LOOP PRESSURE LOSS, BAR	1	1	1	1	N/A	N/A	N/A	N/A	1
58	INTEMEDIATE LOOP PUMP EFFICIENCY	0.9	0.9	0.9	0.9	N/A	N/A	N/A	N/A	0 9
59										
60	MED WATER PLT PERFORMANCE DATA:									
61	DESALINATION TECHNOLOGY	LT-MED	LT-MED	LT-MED	LT-MED	N/A	LT-MED	LT-MED	LT-MED	LT-MED
62	PRODUCT WATER TDS, PPM	25	25	25	25	N/A	25	25	25	25
63	MAXIMUM BRINE TEMPERATURE, C	80	54	91	45	N/A	108	100	65	112
64	SEAWATER TEMPERATURE, C	27	27	27	27	N/A	27	27	27	27
65	MED CONDENSER RANGE, C	5	5	5	5	N/A	5	5	5	5
66	MED CONDENSER APPROACH, C	2	2	2	2	N/A	2	2	2	2
67	MINIMUM CONDENSING TEMPERATURE, C	34	34	34	34	N/A	34	34	34	34
68	OVERALL MED WORKING TEMPERATURE, C	46	20	57	11	N/A	74	66	31	78
69	TEMPERATURE DROP BETWEEN EFFECTS, C	2.52	2.08	2.70	1.91	N/A	2.96	2.83	2.27	3 02
70	NUMBER OF EFFECTS	19	10	22	6	N/A	26	24	14	26
71	GOR, kg PRODUCT/kg STEAM	14.0	8.5	15.4	5.5	N/A	17.2	16.3	11.2	17 2
72	UNIT SIZE, CU M/D	48000	24000	48000	24000	N/A	48000	24000	24000	48000
73	SEAWATER/PRODUCT FLOW RATIO	7.4	12.2	6.7	18.9	N/A	6.0	6.3	9.3	6 0
74	SEAWATER HEAD + PRESS LOSS, BAR	1.7	1 7	1.7	1 7	N/A	1.7	1.7	1.7	1 7
75	SEAWATER PUMP EFFICIENCY	0.9	0 9	0.9	0 9	N/A	0.9	0.9	0.9	0 9
76	WATER PLANT SPEC. PWR USE kWe/CU M/D	0.083	0 083	0 083	0.083	N/A	0.083	0.083	0 083	0 083
77	WTR PLT PLANNED OUTAGE RATE	0.030	0.030	0.030	0.030	N/A	0.030	0.030	0.030	0 030
78	WTR PLT UNPLANNED OUTAGE RATE	0.065	0 065	0.065	0 065	N/A	0.065	0.065	0.065	0 065
79	BACKUP HEAT SOURCE SIZE, MWt	1417	665	1195	1074	N/A	1044	602	461	1000
80	BACKUP HEAT SOURCE AVAILABILITY	0.9	0.9	0.9	0.9	N/A	0.9	0.9	0.9	0 9
81										
82	MEMBRANE WATER PLT PERFORMANCE DATA:									
83	NO STAGES TO MEET WATER STANDARD	1	1	1	1	1	1	1	1	
84	SEAWATER TDS, PPM	38500	38500	38500	38500	38500	38500	38500	38500	N/A
85	RO PRODUCT WATER TDS, PPM	270	270	270	270	270	270	270	270	N/A
86	WATER FLUX INCREASE FACTOR FROM TEMP	1	1.1	1	1 1	1.1	1	1.1	1.1	N/A
87	OUTPUT PER UNIT, CU.M/D	24,000	26,400	24,000	26,400	26,400	24,000	26,400	26,400	N/A
88	RECOVERY RATIO	0.50	0.55	0 50	0.55	0.55	0.50	0.50	0.50	N/A
89	SEAWATER PUMP HEAD, BAR	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	N/A
90	SEAWATER PUMP EFFICIENCY	0.9	0 9	0.9	0 9	0.9	0.9	0.9	0.9	N/A
91	BOOSTER PUMP HEAD, BAR	3.3	3.3	3.3	3.3	3 3	3.3	3.3	3.3	N/A
92	BOOSTER PUMP EFFICIENCY	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	N/A
93	STAGE 1 HIGH HD PUMP PRESS RISE, BAR	82	82	82	82	82	82	82	82	N/A
94	STAGE 1 HIGH HEAD PUMP EFFICIENCY	0.85	0 85	0 85	0 85	0.85	0.85	0.85	0 85	N/A
95	STG 1 HYDRAULIC COUPLING EFFICIENCY	0 965	0 965	0 965	0 965	0 965	0 965	0 965	0 965	N/A

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	A	B	C	D	E	F	G	H	I	J	K
96	i	ENERGY RECOVERY EFFICENCY	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	N/A
97	i	STG 2 HYDRAULIC COUPLING EFFICIENCY	0.965	0.965	0.965	0.965	0.965	0.965	0.965	0.965	N/A
98	i	STAGE 2 HIGH HD PUMP PRESS RISE, BAR	0	0	0	0	0	0	0	0	N/A
99	i	STAGE 2 HIGH HEAD PUMP EFFICIENCY	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	N/A
100	i	OTHER SPECIFIC POWER USE, kWe/CU.M/D	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	N/A
101	i	RO PLANT AVAILABILITY	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	N/A
102											
103		COST INPUT DATA									
104											
105		POWER PLANT COST DATA:									
106	i	SPEC. CONSTR. COST, $/kWe ($/kWt)	2200	2200	2140.41	2140.41	2020	1200	400	600	631
107		ADDITIONL CONSTR. COST, $/kWe ($/kWt)	220	220	214	214	202	120	40	60	63
108		TOTAL CONSTR. COST, $/kWe ($/kWt)	2420	2420	2354	2354	2222	1320	440	660	694
109	i	CONSTRUCTION LEAD TIME, MONTHS	60	60	60	60	48	48	48	36	60
110	i	SPECIFIC O&M COST, $/MWeh ($/MWth)	13.09	13.09	11.00	11.00	8.65	3.30	6.60	5.50	2.75
111	i	GAS PRICE AT STARTUP, $/BOE	N/A	N/A	N/A	N/A	N/A	15.50	15.50	15.50	N/A
112	i	SPECIFIC FUEL COST, $/MWeh ($/MWth)	13.89	13.89	4.35	4.35	9.20	23.53	28.52	18.82	1.60
113		LEVELIZED ANNUAL DECOMM. COST, M$	4.21	2.11	3.16	3.16	2.01	0.00	0.00	0.00	2.44
114	i	FUEL ANNUAL REAL ESCALATION, %	0	0	0	0	0	2	2	2	0
115											
116		THERMAL WATER PLANT COST DATA:									
117	i	CORRECTION FACTOR FOR UNIT SIZE	0.9	0.9	0.9	0.9	N/A	0.9	0.9	0.9	0.9
118	i	BASE UNIT COST, $/CU.M/D	1440	1440	1440	1440	N/A	1440	1440	1440	1440
119		INTERMEDIATE LOOP UNIT COST, $/CU.M/D	79	129	71	201	N/A	0	0	0	64
120	i	WATER PLT COST CONTG'CY FACTOR	0.10	0.10	0.10	0.10	N/A	0.10	0.10	0.10	0.10
121	i	WATER PLT OWNERS COST FACTOR	0.05	0.05	0.05	0.05	N/A	0.05	0.05	0.05	0.05
122	i	WATER PLT LEAD TIME,MONTHS	48	36	60	36	N/A	60	40	36	60
123	i	AVERAGE MANAGEMENT SALARY, $/YR	66000	66000	66000	66000	N/A	66000	66000	66000	66000
124	i	AVERAGE LABOR SALARY, $/YR	29700	29700	29700	29700	N/A	29700	29700	29700	29700
125	i	SPECIFIC O&M SPARE PARTS COST, $/CU.M	0.04	0.04	0.04	0.04	N/A	0.04	0.04	0.04	0.04
126	i	SPECIFIC O&M CHEM COST, $/CU.M	0.02	0.02	0.02	0.02	N/A	0.02	0.02	0.02	0.02
127	i	WATER PLT O&M INS COST,% BASE CAP	0.50	0.50	0.50	0.50	N/A	0.50	0.50	0.50	0.50
128	i	BACKUP HEAT SOURCE UNIT COST, $/MWt	55000	55000	55000	55000	N/A	55000	55000	55000	50000
129											
130		MEMBRANE WATER PLANT COST DATA:									
131	i	BASE UNIT COST, $/CU.M/D	1125	1023	1125	1023	1023	1125	1023	1023	N/A
132	i	WATER PLT COST CONTG'CY FACTOR	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	N/A
133	i	WATER PLT OWNERS COST FACTOR	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	N/A
134	i	WATER PLT LEAD TIME,MONTHS	48	36	48	36	48	48	30	36	N/A
135	i	AVERAGE MANAGEMENT SALARY, $/YR	66000	66000	66000	66000	66000	66000	66000	66000	N/A
136	i	AVERAGE LABOR SALARY, $/YR	29700	29700	29700	29700	29700	29700	29700	29700	N/A
137	i	O&M MEMBRANE REPLACEMENT COST, $/CU.M	0.12	0.11	0.12	0.11	0.11	0.12	0.11	0.11	N/A
138	i	O&M SPARE PARTS COST, $/CU.M	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	N/A
139	i	SPECIFIC CHEMICAL COST, $/CU.M	0.07	0.06	0.07	0.06	0.06	0.07	0.06	0.06	N/A
140	i	WATER PLT O&M INS COST,% BASE CAP	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	N/A
141											
142		ECONOMIC PARAMETERS INPUT DATA:									
143											
144		CASE 1: 5% INTEREST RATE									
145	i	AFUDC RATE, %/YR	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

	A	B	C	D	E	F	G	H	I	J	K
146		LN-94$ FIXED CHARGE RATE, %	6.51	6.51	6.51	6.51	6.51	6.51	6.51	6.51	6.51
147	i	PURCHASED ELECTRICITY COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.04
148											
149		CASE 2: 8% INTEREST RATE									
150	i	AFUDC RATE, %/YR	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
151		LN-94$ FIXED CHARGE RATE, %	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88
152	i	PURCHASED ELECTRICITY COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.05
153											
154		CASE 3: 10% INTEREST RATE									
155	i	AFUDC RATE, %/YR	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
156		LN-94$ FIXED CHARGE RATE, %	10.61	10.61	10.61	10.61	10.61	10.61	10.61	10.61	10.61
157	i	PURCHASED ELECTRICITY COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.06
158											
159		PERFORMANCE CALCULATIONS									
160											
161		SINGLE-PURPOSE PLT PERFORMANCE:									
162		THERMAL POWER, MWt	1899	949	1515	1515	600	1500	1061	900	1000
163		PLANT GROSS OUTPUT, MWe	632	316	474	474	302	632	368	474	N/A
164		PLANT AUX LOADS, MWe	31.6	15.8	23.7	23.7	15.1	31.6	18.4	23.7	10.0
165		CONDENSER COOLING WTR FLOW, kg/s	38782	19391	31807	31807	N/A	23292	N/A	11997	N/A
166		CONDENSER COOLING WTR PUMP POWER, MWe	7.73	3.87	6.34	6.34	N/A	4.65	N/A	2.39	N/A
167		REJECT HEAT LOAD, MWt	1267.2	633.6	1041.5	1041.5	N/A	868.4	N/A	426.3	N/A
168		TURBINE EXHAUST FLOW, kg/s	550.9	275.5	452.8	452.8	N/A	377.6	N/A	185.4	N/A
169		OPERATING AVAILABILITY	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.846
170											
171		DUAL-PURPOSE POWER PLANT PERFORMANCE:									
172		LOST SHAFTWORK, MWs	150.3	31.6	153.3	32.6	N/A	175.9	N/A	35.1	N/A
173		LOST ELECTRICITY PRODUCTION, MWe	149.0	31.3	151.9	32.3	N/A	174.3	0.0	34.8	N/A
174		NET ELECTRICITY PRODUCED, MWe	451.0	268.7	298.1	417.7	N/A	425.7	350.0	415.2	N/A
175		TOTAL HEAT TO WTR PLT, MWt	1417	665	1195	1074	N/A	1044	602	461	1000
176		BACKPRESSURE TURB. EXHAUST FLOW, kg/s	616.3	289.2	519.5	467.0	N/A	454.0	N/A	200.6	N/A
177		INTERMEDIATE LOOP FLOW RATE, kg/s	169556	79571	142916	128473	N/A	N/A	N/A	N/A	119617
178		INTERMEDIATE LOOP PUMPING POWER, MWe	19.89	9.33	16.77	15.07	N/A	N/A	N/A	N/A	14.03
179		FLASH STEAM FLOW TO MED, kg/s	611	287	515	463	N/A	450	259	199	431
180											
181		THERMAL WATER PLANT PERFORMANCE:									
182		MAXIMUM WATER PLT CAPACITY, CU.M/DAY	737341	210871	686586	218627	N/A	667107	365783	191673	638809
183		NUMBER OF UNITS	16	9	15	10	N/A	14	16	8	14
184		SEAWATER FLOW, kg/s	63237	29676	53301	47915	N/A	46588	26845	20586	44612
185		INCREMENTAL SEAWATER PUMPING PWR, MWe	4.88	2.05	4.29	3.21	N/A	4.65	5.35	1.71	8.90
186		WATER PLANT INTERNAL POWER USE, MWe	61.20	17.50	56.99	18.15	N/A	55.37	30.36	15.91	53.02
187		WTR PLT+INT.LOOP+SEAWTR PUMP PWR, MWe	85.97	28.89	78.04	36.43	N/A	60.02	35.71	17.62	75.95
188		WTR PLT OPERATING AVAILABILITY	0.91	0.91	0.91	0.91	N/A	0.91	0.91	0.91	0.91
189		COMBINED HEAT SOURCE AVAILABILITY	0.98	0.98	0.98	0.98	N/A	0.98	0.98	0.98	0.98
190		COMBINED PWR/WTR PLT CAPACITY FACTOR	0.89	0.89	0.89	0.89	N/A	0.89	0.89	0.89	0.89
191		ANNUAL WATER PRODUCTION, CU.M/YR	239,229,787	68,416,875	222,762,307	70,933,237	N/A	216,442,418	118,677,959	62,188,236	208,202,152
192		AVRG DAILY WATER PRODUCTION, CU.M/D	655424	187443	610308	194338	N/A	592993	325145	170379	570417
193											
194		RO WATER PLANT PERFORMANCE:									
195		PRODUCTION CAPACITY, CU.M/DAY	737341	509129	686586	501373	720000	667107	354217	528327	N/A

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	A	B	C	D	E	F	G	H	I	J	K
196		NUMBER OF RO UNITS	31	20	29	19	28	28	14	21	N/A
197		SEAWATER FLOW, kg/s	17068	10714	15893	10551	15152	15442	8199	12230	N/A
198		STAND-ALONE SEAWATER PUMPING PWR, MWe	3.40	N/A	3.17	N/A	N/A	3.08	N/A	N/A	N/A
199		CONTIGUOUS SEAWATER PUMPING PWR, MWe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A
200		BOOSTER PUMP POWER, MWe	6.61	4.15	6.15	4.08	5.87	5.98	3.17	4.73	N/A
201		STAGE 1 HIGH HEAD PUMP POWER, MWe	180.15	113.09	167.75	111.36	159.92	162.99	86.54	129.08	N/A
202		ENERGY RECOVERY, MWe	63.84	36.06	59.44	35.52	51.00	57.76	30.67	45.74	N/A
203		STAGE 2 HIGH HEAD PUMP POWER, MWe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A
204		OTHER POWER, MWe	30.08	18.88	28.01	18.60	26.71	27.22	13.14	19.60	N/A
205		TOTAL STAND-ALONE POWER USE, MWe	156.41	N/A	145.64	N/A	N/A	141.51	N/A	N/A	N/A
206		TOTAL CONTIGUOUS POWER USE, MWe	153.01	100.05	142.47	98.53	141.49	138.43	72.19	107.67	N/A
207		ANNUAL AVG. WATER PRODUCTION, CU.M/YR	244907966	169107234	228049626	166531145	239148000	221579733	117653189	175483711	N/A
208		AVG. DAILY WATER PRODUCTION, CU.M/DAY	670981	463307	624793	456250	655200	607068	322338	480777	N/A
209		SPEC. (S-A) PWR CONSUMPTION, kWh/CU.M	5.09	N/A	5.09	N/A	N/A	5.09	N/A	N/A	N/A
210		SPEC.(CONT) PWR CONSUMPTION, kWh/CU.M	4.98	4.72	4.98	4.72	4.72	4.98	4.89	4.89	N/A
211		NET PWR PLNT SALEABLE PWR (S-A), MWe	443.59	N/A	304.36	N/A	N/A	458.49	N/A	N/A	N/A
212		NET PWR PLNT SALEABLE PWR (CONT), MWe	446.99	N/A	307.53	N/A	145.51	461.57	N/A	N/A	N/A
213											
214		COST CALCULATIONS									
215											
216		THERMAL WATER PLANT COSTS:									
217		NUMBER OF UNITS	16	9	15	10	N/A	14	16	8	14
218		CORRECTION FACTOR FOR NO. OF UNITS	0.725	0.823	0.725	0.802	N/A	0.725	0.725	0.844	0.725
219		WATER PLT SPECIFIC BASE COST,$/CU.M/D	940	1067	940	1040	N/A	940	940	1094	940
220		INC. IN/OUTFALL SPEC. BS CT, $/CU.M/D	29	57	29	71	N/A	36	138	62	107
221		INTERMEDIATE LOOP COST, $/CU.M/D	79	129	71	201	N/A	0	0	0	64
222		TOTAL SPECIFIC BASE COST, $/CU.M/D	1047	1253	1040	1312	N/A	975	1077	1156	1111
223		NUMBER OF MANAGEMENT PERSONNEL	18	8	17	8	N/A	17	11	8	16
224		WATER PLT O&M MGMT COST,M$/Y	1.19	0.53	1.12	0.53	N/A	1.12	0.73	0.53	1.06
225		NUMBER OF LABOR PERSONNEL	72	44	70	45	N/A	70	55	42	68
226		WATER PLT O&M LABOR COST,M$/Y	2.15	1.30	2.09	1.32	N/A	2.07	1.62	1.25	2.03
227		WATER PLT ADJUSTED BASE COST,M$	772.28	264.25	714.30	286.91	N/A	650.66	394.03	221.62	709.47
228		BACKUP HEAT SOURCE BASE COST, M$	77.96	36.59	65.71	59.07	N/A	57.44	33.10	25.38	50.00
229		TOTAL WATER PLANT BASE COST, M$	850.24	300.84	780.01	345.98	N/A	708.10	427.13	247.00	759.47
230		WATER PLT OWNERS COST,M$	42.51	15.04	39.00	17.30	N/A	35.40	21.36	12.35	37.97
231		WATER PLT CONTINGENCY ,M$	89.28	31.59	81.90	36.33	N/A	74.35	44.85	25.93	79.74
232		WATER PLT TOT CONSTRUCTION COST ,M$	982.03	347.47	900.91	399.60	N/A	817.85	493.33	285.28	877.19
233		WATER PLT O&M COST,M$/YR	21.55	7.26	20.15	7.54	N/A	19.43	11.44	6.62	19.13
234											
235		RO WATER PLANT COSTS:									
236		NUMBER OF UNITS	31	20	29	19	28	28	14	21	N/A
237		CORRECTION FACTOR FOR NO. OF UNITS	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725	N/A
238		PROCESS PLT SPECIFIC COST,$/CU.M/D	816	741	816	741	741	816	741	741	N/A
239		STND-ALN IN/OUTFALL SPEC.CT, $/CU.M/D	52	N/A	54	N/A	N/A	54	N/A	N/A	N/A
240		STND-ALN WTR PLNT SPEC. CT, $/CU.M/D	868	N/A	869	N/A	N/A	870	N/A	N/A	N/A
241		NUMBER OF MANAGEMENT PERSONNEL	18	12	17	12	16	17	10	13	N/A
242		O&M MGMT COST,M$/Y	1.19	0.79	1.12	0.79	1.06	1.12	0.66	0.86	N/A
243		NUMBER OF LABOR PERSONNEL	72	57	70	56	65	70	49	58	N/A
244		O&M LABOR COST,M$/Y	2.15	1.69	2.09	1.68	1.94	2.07	1.46	1.71	N/A
245		STND-ALN WTR PLT ADJUSTED BASE CT,M$	639.76	N/A	596.76	N/A	N/A	580.24	N/A	N/A	N/A

	A	B	C	D	E	F	G	H	I	J	K
246		CONTIGUOUS WTR PLT ADJUSTED BS CT,M$	601.39	377.51	560.00	371.76	533.86	544.11	262.64	391.74	N/A
247		WATER PLT OWNERS COST,M$	31.99	18.88	29.84	18.59	26.69	29.01	13.13	19.59	N/A
248		WATER PLT CONTINGENCY ,M$	67.17	39.64	62.66	39.03	56.06	60.93	27.58	41.13	N/A
249		STND-ALN WTR PLT TOT CONSTRUCT CT, M$	738.92	N/A	689.25	N/A	N/A	670.18	N/A	N/A	N/A
250		CONTIGUOUS WTR PLT TOT CONSTR CT, M$	700.56	436.02	652.49	429.38	616.61	634.05	303.35	452.46	N/A
251		WATER PLT O&M COST,M$/YR	60.42	38.19	56.37	37.63	53.49	54.84	26.96	39.62	N/A
252											
253		ECONOMIC EVALUATIONS									
254											
255		CASE 1: 5% INTEREST RATE									
256		-POWER PLANT COST									
257		TOTAL CONSTRUCTION COST, M$	1452.00	726.00	1059.51	1059.51	637.71	792.00	154.00	297.00	694.10
258		AFUDC, M$	188.36	94.18	137.45	137.45	65.37	81.18	15.79	22.55	90.04
259		TOTAL PLANT INVESTMENT, M$	1640.36	820.18	1196.95	1196.95	703.08	873.18	169.79	319.55	784.14
260		LEVELIZED ANNUAL CAPITAL COST, M$	106.71	53.35	77.86	77.86	45.74	56.80	11.04	20.79	51.01
261		*FUEL LEVELIZED FACTOR*	1.00	1.00	1.00	1.00	1.00	1.60	1.60	1.60	1.00
262		ANNUAL FUEL COST, M$	58.48	29.24	13.74	13.74	18.53	158.22	111.87	94.93	11.85
263		ANNUAL O&M COST, M$	55.11	27.55	34.73	34.73	17.41	13.89	16.21	17.37	20.37
264		ELEC. PWR COST (HEAT ONLY), M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.96
265		DECOMMISSIONING COST, M$	4.21	2.11	3.16	3.16	2.01	0.00	0.00	0.00	2.44
266		TOTAL ANNUAL REQUIRED REVENUE, M$	224.51	112.25	129.49	129.49	83.69	228.92	139.13	133.09	88.64
267		ANNUAL ELECTRICITY PRODUCTION, KWH	4,210,056,000	2,105,028,000	3,157,542,000	3,157,542,000	2,013,810,120	4,210,056,000	2,455,866,000	3,157,542,000	N/A
268		LEVELIZED POWER COST, $/kWh	0.053	0.053	0.041	0.041	0.042	0.054	0.057	0.042	N/A
269											
270		-THERMAL (MED) PLANT:									
271		ANNUAL WATER PROD, CU.M/YR	239229787.3	68416874.5	222762306.7	70933237.02	N/A	216442417.8	118677959.5	62188235.87	208202151.6
272		TOTAL CONSTRUCTION COST, M$	982.03	347.47	900.91	399.60	N/A	817.85	493.33	285.28	877.19
273		AFUDC ,M$	100.66	26.38	116.87	30.34	N/A	106.10	41.79	21.66	113.79
274		TOTAL INVESTMENT ,M$	1082.68	373.85	1017.79	429.95	N/A	923.95	535.13	306.95	990.99
275		WATER CT, FIXED CHARGE, M$/YR	70.43	24.32	66.21	27.97	N/A	60.10	34.81	19.97	64.47
276		WATER CT, HEAT CHARGE, M$/YR	61.86	13.02	48.51	10.31	N/A	73.79	N/A	11.43	88.64
277		WATER CT, ELEC CHARGE, M$/YR	35.70	12.00	24.92	11.63	N/A	25.41	15.75	5.78	23.76
278		WATER CT, O&M CHARGE, M$/YR	21.55	7.26	20.15	7.54	N/A	19.43	11.44	6.62	19.13
279		TOTAL WATER COST, $/CU.M	0.79	0.83	0.72	0.81	N/A	0.83	0.52	0.70	0.94
280											
281		-STAND-ALONE RO PLANT:									
282		SPECIFIED OUTPUT									
283		ANNUAL WATER PROD, CU.M/YR	244907966.4	N/A	228049626	N/A	N/A	221579732.9	N/A	N/A	N/A
284		TOTAL CONSTRUCTION COST ,M$	738.92	N/A	689.25	N/A	N/A	670.18	N/A	N/A	N/A
285		AFUDC ,M$	75.74	N/A	70.65	N/A	N/A	68.69	N/A	N/A	N/A
286		TOTAL INVESTMENT ,M$	814.66	N/A	759.90	N/A	N/A	738.87	N/A	N/A	N/A
287		WATER CT, FIXED CHARGE, M$/YR	52.99	N/A	49.43	N/A	N/A	48.06	N/A	N/A	N/A
288		WATER CT, ELEC CHARGE, M$/YR	66.49	N/A	47.61	N/A	N/A	61.34	N/A	N/A	N/A
289		WATER CT, O&M CHARGE, M$/YR	60.42	N/A	56.37	N/A	N/A	54.84	N/A	N/A	N/A
290		TOTAL WATER COST, $/CU.M	0.73	N/A	0.67	N/A	N/A	0.74	N/A	N/A	N/A
291		-CONTIGUOUS RO PLANT:									
292		ANNUAL WATER PROD, CU.M/YR	244907966.4	169107233.8	228049626	166531144.8	239148000	221579732.9	117653189.4	175483710.7	N/A
293		TOTAL CONSTRUCTION COST ,M$	700.56	436.02	652.49	429.38	616.61	634.05	303.35	452.46	N/A
294		AFUDC ,M$	71.81	33.11	66.88	32.60	63.20	64.99	19.08	34.36	N/A
295		TOTAL INVESTMENT ,M$	772.36	469.13	719.37	461.98	679.82	699.04	322.43	486.82	N/A

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	A	B	C	D	E	F	G	H	I	J	K
296		WATER CT, FIXED CHARGE, M$/YR	50.24	30.52	46.80	30.05	44.22	45.47	20.97	31.67	N/A
297		WATER CT, ELEC CHARGE, M$/YR	65.04	42.53	46.58	32.21	46.87	60.00	32.60	36.18	N/A
298		WATER CT, O&M CHARGE, M$/YR	60.42	38.19	56.37	37.63	53.49	54.84	26.96	39.62	N/A
299		TOTAL WATER COST, $/CU.M	0.72	0.66	0.66	0.60	0.60	0.72	0.68	0.61	N/A
300											
301		HYBRID MED/RO									
302		HYBRID ANNUAL WATER PRODUCTION	N/A	237,524,108	N/A	237,464,382	N/A	N/A	236,331,149	237,671,947	N/A
303		COMBINED WTR COST FOR HYBRID, $/CU.M	N/A	0.71	N/A	0.66	N/A	N/A	0.60	0.64	N/A
304											
305		CASE 2: 8% INTEREST RATE									
306		-POWER PLANT COST									
307		TOTAL CONSTRUCTION COST, M$	1452.00	726.00	1059.51	1059.51	637.71	792.00	154.00	297.00	694.10
308		AFUDC, M$	308.05	154.03	224.78	224.78	106.12	131.79	25.63	36.34	147.26
309		TOTAL PLANT INVESTMENT, M$	1760.05	880.03	1284.29	1284.29	743.83	923.79	179.63	333.34	841.36
310		LEVELIZED ANNUAL CAPITAL COST, M$	156.34	78.17	114.08	114.08	66.07	82.06	15.96	29.61	74.74
311		FUEL LEVELIZED FACTOR	1.00	1.00	1.00	1.00	1.00	1.54	1.54	1.54	1.00
312		ANNUAL FUEL COST, M$	58.48	29.24	13.74	13.74	18.53	152.49	107.82	91.49	11.85
313		ANNUAL O&M COST, M$	55.11	27.55	34.73	34.73	17.41	13.89	16.21	17.37	20.37
314		DECOMMISSIONING COST, M$	4.21	2.11	3.16	3.16	2.01	0.00	0.00	0.00	2.44
315		ELECTRIC POWER COST (HEATONLY), M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.70
316		TOTAL ANNUAL REQUIRED REVENUE, M$	274.14	137.07	165.71	165.71	104.02	248.44	139.99	138.47	113.10
317		ANNUAL ELECTRICITY PRODUCTION, KWH	4,210,056,000	2,105,028,000	3,157,542,000	3,157,542,000	2,013,810,120	4,210,056,000	2,455,866,000	3,157,542,000	N/A
318		LEVELIZED POWER COST, $/kWh	0.065	0.065	0.052	0.052	0.052	0.059	0.057	0.044	N/A
319											
320		-THERMAL (MED) PLANT:									
321		TOTAL CONSTRUCTION COST, M$	982.03	347.47	900.91	399.60	N/A	817.85	493.33	285.28	877.19
322		AFUDC, M$	163.41	42.52	191.14	48.90	N/A	173.51	67.52	34.91	186.10
323		TOTAL WATER PLANT INVESTMENT, M$	1145.44	389.99	1092.05	448.50	N/A	991.37	560.85	320.19	1063.29
324		WATER CT, FIXED CHARGE, M$/YR	101.75	34.64	97.00	39.84	N/A	88.06	49.82	28.44	94.45
325		WATER CT, HEAT CHARGE, M$/YR	75.54	15.90	62.08	13.19	N/A	80.09	0.00	11.89	113.10
326		WATER CT, ELEC CHARGE, M$/YR	43.59	14.65	31.89	14.89	N/A	27.58	15.85	6.02	29.70
327		WATER CT, O&M CHARGE, M$/YR	21.55	7.26	20.15	7.54	N/A	19.43	11.44	6.62	19.13
328		TOTAL WATER COST, $/CU.M	1.01	1.06	0.95	1.06	N/A	0.99	0.65	0.85	1.23
329											
330		-STAND-ALONE RO PLANT:									
331		TOTAL CONSTRUCTION COST ,M$	738.92	N/A	689.25	N/A	N/A	670.18	N/A	N/A	N/A
332		AFUDC ,M$	122.96	N/A	114.69	N/A	N/A	111.52	N/A	N/A	N/A
333		TOTAL INVESTMENT ,M$	861.88	N/A	803.94	N/A	N/A	781.69	N/A	N/A	N/A
334		WATER CT, FIXED CHARGE, M$/YR	76.56	N/A	71.41	N/A	N/A	69.44	N/A	N/A	N/A
335		WATER CT, ELEC CHARGE, M$/YR	81.19	N/A	60.93	N/A	N/A	66.57	N/A	N/A	N/A
336		WATER CT, O&M CHARGE, M$/YR	60.42	N/A	56.37	N/A	N/A	54.84	N/A	N/A	N/A
337		TOTAL WATER COST, $/CU.M	0.89	N/A	0.83	N/A	N/A	0.86	N/A	N/A	N/A
338		-CONTIGUOUS RO PLANT:									
339		TOTAL CONSTRUCTION COST ,M$	700.56	436.02	652.49	429.38	616.61	634.05	303.35	452.46	N/A
340		AFUDC ,M$	116.57	53.36	108.58	52.54	102.60	105.51	30.63	55.37	N/A
341		TOTAL INVESTMENT ,M$	817.13	489.38	761.07	481.92	719.22	739.55	333.99	507.83	N/A
342		WATER CT, FIXED CHARGE, M$/YR	72.58	43.47	67.60	42.81	63.89	65.69	29.67	45.11	N/A
343		WATER CT, ELEC CHARGE, M$/YR	79.42	51.93	59.60	41.22	58.26	65.12	32.80	37.64	N/A
344		WATER CT, O&M CHARGE, M$/YR	60.42	38.19	56.37	37.63	53.49	54.84	26.96	39.62	N/A
345		TOTAL WATER COST, $/CU.M	0.87	0.79	0.80	0.73	0.73	0.84	0.76	0.70	N/A

	A	B	C	D	E	F	G	H	I	J	K
346											
347		HYBRID MED/RO									
348		HYBRID ANNUAL WATER PRODUCTION	N/A	237,524,108	N/A	237,464,382	N/A	N/A	236,331,149	237,671,947	N/A
349		COMBINED WTR COST FOR HYBRID, $/CU.M	N/A	0.87	N/A	0.83	N/A	N/A	0.70	0.74	N/A
350											
351		CASE 3: 10% INTEREST RATE									
352		POWER PLANT COST									
353		TOTAL CONSTRUCTION COST, M$	1452.00	726.00	1059.51	1059.51	637.71	792.00	154.00	297.00	694.10
354		AFUDC, M$	390.67	195.34	285.07	285.07	133.92	166.32	32.34	45.65	186.75
355		TOTAL PLANT INVESTMENT, M$	1842.67	921.34	1344.57	1344.57	771.63	958.32	186.34	342.65	880.85
356		LEVELIZED ANNUAL CAPITAL COST, M$	195.47	97.73	142.63	142.63	81.85	101.66	19.77	36.35	93.44
357		FUEL LEVELIZED FACTOR	1.00	1.00	1.00	1.00	1.00	1.51	1.51	1.51	1.00
358		ANNUAL FUEL COST, M$	58.48	29.24	13.74	13.74	18.53	149.27	105.55	89.56	11.85
359		ANNUAL O&M COST, M$	55.11	27.55	34.73	34.73	17.41	13.89	16.21	17.37	20.37
360		DECOMMISSIONING COST, M$	4.21	2.11	3.16	3.16	2.01	0.00	0.00	0.00	2.44
361		ELEC. PWR COST (HEAT ONLY), M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.44
362		TOTAL ANNUAL REQUIRED REVENUE, M$	313.27	156.63	194.26	194.26	119.81	264.82	141.52	143.28	132.55
363		ANNUAL ELECTRICITY PRODUCTION, KWH	4,210,056,000	2,105,028,000	3,157,542,000	3,157,542,000	2,013,810,120	4,210,056,000	2,455,866,000	3,157,542,000	N/A
364		LEVELIZED POWER COST, $/kWh	0.074	0.074	0.062	0.062	0.059	0.063	0.058	0.045	N/A
365											
366		THERMAL (MED) PLANT:									
367		TOTAL CONSTRUCTION COST	982.03	347.47	900.91	399.60	N/A	817.85	493.33	285.28	877.19
368		AFUDC ,M$	206.23	53.40	242.40	61.42	N/A	220.05	84.93	43.85	236.02
369		TOTAL INVESTMENT ,M$	1188.25	400.87	1143.31	461.02	N/A	1037.90	578.27	329.13	1113.21
370		WATER CT, FIXED CHARGE, M$/YR	126.05	42.52	121.28	48.90	N/A	110.10	61.34	34.91	118.09
371		WATER CT, HEAT CHARGE, M$/YR	86.32	18.16	72.78	15.46	N/A	85.37	0.00	12.30	132.55
372		WATER CT, ELEC CHARGE, M$/YR	49.81	16.74	37.39	17.45	N/A	29.40	16.03	6.23	35.65
373		WATER CT, O&M CHARGE, M$/YR	21.55	7.26	20.15	7.54	N/A	19.43	11.44	6.62	19.13
374		TOTAL WATER COST, $/CU.M	1.19	1.24	1.13	1.26	N/A	1.13	0.75	0.97	1.47
375											
376		STAND-ALONE RO PLANT:									
377		TOTAL CONSTRUCTION COST, M$	738.92	N/A	689.25	N/A	N/A	670.18	N/A	N/A	N/A
378		AFUDC, M$	155.17	N/A	144.74	N/A	N/A	140.74	N/A	N/A	N/A
379		TOTAL INVESTMENT ,M$	894.10	N/A	834.00	N/A	N/A	810.91	N/A	N/A	N/A
380		WATER CT, FIXED CHARGE, M$/YR	94.85	N/A	88.47	N/A	N/A	86.02	N/A	N/A	N/A
381		WATER CT, ELEC CHARGE, M$/YR	92.78	N/A	71.43	N/A	N/A	70.96	N/A	N/A	N/A
382		WATER CT, O&M CHARGE, M$/YR	60.42	N/A	56.37	N/A	N/A	54.84	N/A	N/A	N/A
383		TOTAL WATER COST, $/CU.M	1.01	N/A	0.95	N/A	N/A	0.96	N/A	N/A	N/A
384		CONTIGUOUS RO PLANT:									
385		TOTAL CONSTRUCTION COST, M$	700.56	436.02	652.49	429.38	616.61	634.05	303.35	452.46	N/A
386		AFUDC, M$	147.12	67.01	137.02	65.99	129.49	133.15	38.38	69.54	N/A
387		TOTAL INVESTMENT ,M$	847.67	503.03	789.52	495.37	746.10	767.20	341.74	522.00	N/A
388		WATER CT, FIXED CHARGE, M$/YR	89.92	53.36	83.75	52.55	79.15	81.38	36.25	55.37	N/A
389		WATER CT, ELEC CHARGE, M$/YR	90.76	59.35	69.87	48.32	67.10	69.41	33.16	38.95	N/A
390		WATER CT, O&M CHARGE, M$/YR	60.42	38.19	56.37	37.63	53.49	54.84	26.96	39.62	N/A
391		TOTAL WATER COST, $/CU.M	0.98	0.89	0.92	0.83	0.84	0.93	0.82	0.76	N/A
392											
393		HYBRID MED/RO									
394		HYBRID ANNUAL WATER PRODUCTION	N/A	237,524,108	N/A	237,464,382	N/A	N/A	236,331,149	237,671,947	N/A
395		COMBINED WTR COST FOR HYBRID, $/CU.M	N/A	0.99	N/A	0.96	N/A	N/A	0.78	0.82	N/A

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	A	B	C	D	E	F	G	H	I	J	K
396											
397		SUMMARY									
398											
399		CASE	Libya-1	Libya-2	Libya-3	Libya-4	Libya-5	Libya-6	Libya-7	Libya-8	Libya-9
400		PLANT TYPE	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	FOSSIL	FOSSIL	FOSSIL	NUCLEAR
401		PRODUCT	HEAT & POWER	HEAT & POWER	HEAT & POWER	HEAT & POWER	POWER ONLY	HEAT & POWER	HEAT & POWER	HEAT & POWER	HEAT ONLY
402		REFERENCE OF FLOW DIAGRAM	I, II	III	I, II	III	IV B	VI, VII	XII	XV	V
403		WATER PLANT TYPE	MED OR RO	MED/RO HYBRID	MED OR RO	MED/RO HYBRID	RO	MED OR RO	MED/RO HYBRID	MED/RO HYBRID	MED
404		REACTOR TYPE	PWR(NP-300)	PWR(NP-300)	CANDU-3	CANDU-3	GT-MHR	STEAM TURBINE	GAS TURBINE	COMBINED CYCLE	AST-500
405		SELECTED NET OUTPUT, MWe (MWt)	600	300	450	450	287	600	350	450	1000
406		PRODUCT DRINKING WATER STANDARD	WHO	WHO	WHO	WHO	WHO	WHO	WHO	WHO	WHO
407											
408		SUMMARY CASE 1: 6% INT & AFUDC RATE									
409		-LEVELIZED POWER COST, $/kWh	0.053	0 053	0 041	0 041	0.042	0.054	0.057	0.042	N/A
410		-PURCHASED POWER COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.04
411		-THERMAL MED PLANT (OPTIMIZED)									
412		WATER PRODUCTION CAPACITY, CU.M/D	737341	210871	686586	218627	N/A	667107	365783	191673	638809
413		NET SALEABLE POWER, MWe	365.06	N/A	220.04	N/A	N/A	365.69	N/A	N/A	N/A
414		WATER COST, $/CU.M	0.79	0.83	0.72	0.81	N/A	0.83	0.52	0.70	0.94
415		-STAND-ALONE RO PLT (MED EQ. OUTPUT)									
416		WATER PRODUCTION CAPACITY, CU.M/D	737341	N/A	686586	N/A	N/A	667107	N/A	N/A	N/A
417		NET SALEABLE POWER, MWe	443.59	N/A	304.36	N/A	N/A	458.49	N/A	N/A	N/A
418		WATER COST, $/CU.M	0.73	N/A	0.67	N/A	N/A	0.74	N/A	N/A	N/A
419		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)									
420		WATER PRODUCTION CAPACITY, CU.M/D	737341	509129	686586	501373	720000	667107	354217	528327	N/A
421		NET SALEABLE POWER, MWe	446.99	N/A	307.53	N/A	145.51	461.57	N/A	N/A	N/A
422		WATER COST, $/CU.M	0.72	0 66	0.66	0 60	0.60	0.72	0.68	0.61	N/A
423		-HYBRID COMBINED MED/RO									
424		WATER PRODUCTION CAPACITY, CU.M/D	N/A	720000	N/A	720000	N/A	N/A	720000	720000	N/A
425		NET SALEABLE POWER, MWe	N/A	140	N/A	283	N/A	N/A	242	290	N/A
426		WATER COST, $/CU.M	N/A	0 71	N/A	0.66	N/A	N/A	0.60	0.64	N/A
427											
428		SUMMARY CASE 2: 8% INT & AFUDC RATE									
429		-LEVELIZED POWER COST, $/kWh	0 065	0 065	0 052	0 052	0.052	0.059	0.057	0.044	N/A
430		-PURCHASED POWER COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.05
431		-THERMAL MED PLANT (OPTIMIZED)									
432		WATER PRODUCTION CAPACITY, CU.M/D	737341	210871	686586	218627	N/A	667107	365783	191673	638809
433		NET SALEABLE POWER, MWe	365.06	N/A	220.04	N/A	N/A	365.69	N/A	N/A	N/A
434		WATER COST, $/CU.M	1.01	1.06	0.95	1 06	N/A	0.99	0.65	0.85	1.23
435		-STAND-ALONE RO PLT (MED EQ. OUTPUT)									
436		WATER PRODUCTION CAPACITY, CU.M/D	737341	N/A	686586	N/A	N/A	667107	N/A	N/A	N/A
437		NET SALEABLE POWER, MWe	443.59	N/A	304.36	N/A	N/A	458.49	N/A	N/A	N/A
438		WATER COST, $/CU.M	0.89	N/A	0.83	N/A	N/A	0.86	N/A	N/A	N/A
439		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)									
440		WATER PRODUCTION CAPACITY, CU.M/D	737341	509129	686586	501373	720000	667107	354217	528327	N/A
441		NET SALEABLE POWER, MWe	446.99	N/A	307.53	N/A	145.51	461.57	N/A	N/A	N/A
442		WATER COST, $/CU.M	0.87	0.79	0.80	0.73	0.73	0.84	0.76	0.70	N/A
443		-HYBRID COMBINED MED/RO									
444		WATER PRODUCTION CAPACITY, CU.M/D	N/A	720000	N/A	720000	N/A	N/A	720000	720000	N/A
445		NET SALEABLE POWER, MWe	N/A	140	N/A	283	N/A	N/A	242	290	N/A

	A	B	C	D	E	F	G	H	I	J	K
446		WATER COST, $/CU.M	N/A	0.87	N/A	0.83	N/A	N/A	0.70	0.74	N/A
447											
448		SUMMARY CASE 3: 10% INT & AFUDC RATE									
449		-LEVELIZED POWER COST, $/kWh	0.074	0.074	0.062	0.062	0.059	0.063	0.058	0.045	N/A
450		-PURCHASED POWER COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.06
451		-THERMAL MED PLANT (OPTIMIZED)									
452		WATER PRODUCTION CAPACITY, CU.M/D	737341	210871	686586	218627	N/A	667107	365783	191673	638809
453		NET SALEABLE POWER, MWe	365.06	N/A	220.04	N/A	N/A	365.69	N/A	N/A	N/A
454		WATER COST, $/CU.M	1.19	1.24	1.13	1.26	N/A	1.13	0.75	0.97	1.47
455		-STAND ALONE RO PLT (MED EQ. OUTPUT)									
456		WATER PRODUCTION CAPACITY, CU.M/D	737341	N/A	686586	N/A	N/A	667107	N/A	N/A	N/A
457		NET SALEABLE POWER, MWe	443.59	N/A	304.36	N/A	N/A	458.49	N/A	N/A	N/A
458		WATER COST, $/CU.M	1.01	N/A	0.95	N/A	N/A	0.96	N/A	N/A	N/A
459		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)									
460		WATER PRODUCTION CAPACITY, CU.M/D	737341	509129	686586	501373	720000	667107	354217	528327	N/A
461		NET SALEABLE POWER, MWe	446.99	N/A	307.53	N/A	145.51	461.57	N/A	N/A	N/A
462		WATER COST, $/CU.M	0.98	0.89	0.92	0.83	0.84	0.93	0.82	0.76	N/A
463		-HYBRID COMBINED MED/RO									
464		WATER PRODUCTION CAPACITY, CU.M/D	N/A	720000	N/A	720000	N/A	N/A	720000	720000	N/A
465		NET SALEABLE POWER, MWe	N/A	140	N/A	283	N/A	N/A	242	290	N/A
466		WATER COST, $/CU.M	N/A	0.99	N/A	0.96	N/A	N/A	0.78	0.82	N/A
467											
468		INVESTMENT COSTS - 8% INTEREST RATE									
469											
470		POWER PLANT									
471		SPECIFIC CONSTRUCTION COST, $/kW	2420	2420	2354	2354	2222	1320	440	660	694
472		- POWER PLANT CONSTRUCTION, M$	1452	726	1060	1060	638	792	154	297	694
473		- POWER PLANT IDC, M$	308	154	225	225	106	132	26	36	147
474		TOTAL INVESTMENT COST, M$	1760	880	1284	1284	744	924	180	333	841
475		SPECIFIC INVESTMENT COST, $/kW	2933	2933	2854	2854	2592	1540	513	741	841
476											
477		POWER & THERMAL MED PLANT									
478		- POWER PLANT CONSTRUCTION, M$	1452	726	1060	1060	638	792	154	297	694
479		- POWER PLANT IDC, M$	308	154	225	225	106	132	26	36	147
480		-PWR PLT COST PORTION OF WTR PROD M$	689	470	656	477	N/A	361	55	119	841
481		- MED PLANT CONSTRUCTION, M$	982	347	901	400	N/A	818	493	285	877
482		- MED PLANT IDC, M$	163	43	191	49	N/A	174	68	35	186
483		TOTAL INVESTMENT COST, M$	1835	860	1748	926	N/A	1352	616	439	1905
484		- MED CAPACITY, CU.M/D	737341	210871	686586	218627	N/A	667107	365783	191673	638809
485		SPECIFIC INVESTMENT COST, $/CU.M/D	2488	4079	2546	4235	N/A	2027	1685	2289	2982
486											
487		POWER & S-A RO (MED EQUIV.) PLANT									
488		- POWER PLANT CONSTRUCTION, M$	1452	N/A	1060	N/A	N/A	792	N/A	N/A	N/A
489		- POWER PLANT IDC, M$	308	N/A	225	N/A	N/A	132	N/A	N/A	N/A
490		-PWR PLT COST PORTION OF WTR PROD M$	459	N/A	416	N/A	N/A	218	N/A	N/A	N/A
491		- RO PLANT CONSTRUCTION, M$	739	N/A	689	N/A	N/A	670	N/A	N/A	N/A
492		- RO PLANT IDC, M$	123	N/A	115	N/A	N/A	112	N/A	N/A	N/A
493		TOTAL INVESTMENT COST, M$	1321	N/A	1220	N/A	N/A	1000	N/A	N/A	N/A
494		- RO (MED EQUIV.) CAPACITY, CU.M/D	737341	N/A	686586	N/A	N/A	667107	N/A	N/A	N/A
495		SPECIFIC INVESTMENT COST, $/CU.M/D	1791	N/A	1776	N/A	N/A	1498	N/A	N/A	N/A

LIBYA.XLS

	A	B	C	D	E	F	G	H	I	J	K
496											
497		COST SUMMARY: 8% INTEREST RATE									
498											
499		-POWER PLANT COST									
500		TOTAL PLANT INVESTMENT, M$	1760.05	880.03	1284.29	1284.29	743.83	923.79	179.63	333.34	841.36
501		LEVELIZED ANNUAL CAPITAL COST, M$	156.34	78.17	114.08	114.08	66.07	82.06	15.96	29.61	74.74
502		TOTAL ANNUAL REQUIRED REVENUE, M$	274.14	137.07	165.71	165.71	104.02	248.44	139.99	138.47	113.10
503		LEVELIZED POWER COST, $/kWh	0.065	0.065	0.052	0.052	0.052	0.059	0.057	0.044	N/A
504											
505		-THERMAL (MED) PLANT:									
506		TOTAL WATER PLANT INVESTMENT, M$	1145.44	389.99	1092.05	448.50	N/A	991.37	560.85	320.19	1063.29
507		WATER CT, FIXED CHARGE, $/CU.M	0.43	0.51	0.44	0.56	N/A	0.41	0.42	0.46	0.45
508		WATER CT, ENERGY CHARGE, $/CU.M	0.50	0.45	0.42	0.40	N/A	0.50	0.13	0.29	0.69
509		WATER CT, O&M CHARGE, $/CU.M	0.09	0.11	0.09	0.11	N/A	0.09	0.10	0.11	0.09
510		TOTAL WATER COST, $/CU.M	1.01	1.06	0.95	1.06	N/A	0.99	0.65	0.85	1.23
511											
512		-STAND-ALONE RO PLANT:									
513		TOTAL INVESTMENT ,M$	861.88	N/A	803.94	N/A	N/A	781.69	N/A	N/A	N/A
514		WATER CT, FIXED CHARGE, $/CU.M	0.31	N/A	0.31	N/A	N/A	0.31	N/A	N/A	N/A
515		WATER CT, ENERGY CHARGE, $/CU.M	0.33	N/A	0.27	N/A	N/A	0.30	N/A	N/A	N/A
516		WATER CT, O&M CHARGE, $/CU.M	0.25	N/A	0.25	N/A	N/A	0.25	N/A	N/A	N/A
517		TOTAL WATER COST, $/CU.M	0.89	N/A	0.83	N/A	N/A	0.86	N/A	N/A	N/A
518											
520		-CONTIGUOUS RO PLANT:									
521		TOTAL INVESTMENT ,M$	817.13	489.38	761.07	481.92	719.22	739.55	333.99	507.83	N/A
522		WATER CT, FIXED CHARGE, $/CU.M	0.30	0.26	0.30	0.26	0.27	0.30	0.25	0.26	N/A
523		WATER CT, ENERGY CHARGE, $/CU.M	0.32	0.31	0.26	0.25	0.24	0.29	0.28	0.21	N/A
524		WATER CT, O&M CHARGE, $/CU.M	0.25	0.23	0.25	0.23	0.22	0.25	0.23	0.23	N/A
525		TOTAL WATER COST, $/CU.M	0.87	0.79	0.80	0.73	0.73	0.84	0.76	0.70	N/A

ANNEX II

COUPLING BETWEEN SELECTED ENERGY SOURCES AND DESALINATION PROCESSES

FOR EL-DABAA, EGYPT (240,000 m^3/d)

(MATRIX AND SPREADSHEETS)

TABLE II.1: El-Dabaa, Egypt - 240,000 m^3/d

Primary Energy	Energy Cycle	Scheme	MED	Stand Alone RO	Contiguous RO	Hybrid
Nuclear	Steam Power Plant		I	II-A	II-B	III
		AP600	Egypt-4	Egypt-4	Egypt-4	
		CANDU 3	Egypt-3	Egypt-3	Egypt-3	
		CANDU 6	Egypt-5	Egypt-5	Egypt-5	Egypt-2
		NP-300	Egypt-1	Egypt-1	Egypt-1	
Fossil	Gas Turbine Combined Cycle			XIII-A	XIII-B	XIV
		oil/gas		Egypt-7	Egypt-7	Egypt-6

* Data given in this table are only indicative

IAEA DESALINATION COST ANALYSIS - REGIONAL STUDY

EGYPT.XLS

EGYPT SITE WITH WHO WATER QUALITY STANDARD

30-Sep-94

(All values in U.S. Jan.94 $)

Row	SPREADSHEET ORGANIZATION	START ROW #	END ROW #
7	PLANT CHARACTERISTICS	17	38
8	PERFORMANCE INPUT DATA	40	101
9	COST INPUT DATA	103	140
10	ECONOMIC PARAMETER INPUT DATA	142	157
11	PERFORMANCE CALCULATIONS	159	212
12	COST CALCULATIONS	214	251
13	ECONOMIC EVALUATIONS	253	395
14	SUMMARY	396	524

15 I (I = input data)

Row	A	B	C	D	E	F	G	H	I
16		PLANT AND SITE CHARACTERISTICS							
18	I	CASE	Egypt-1	Egypt-2	Egypt-3	Egypt-4	Egypt-5	Egypt-6	Egypt-7
19	I	ASSUMED LOCATION	EL-DABAA	EL-DABAA	EL-DABAA	EL-DABAA	EL-DABAA	EL-DABAA	EL-DABAA
20	I	WATER DEMAND, CU M/D	240000	240000	240000	240000	240000	240000	240000
21	I	PLANT TYPE	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	FOSSIL	FOSSIL
22	I	PRODUCT	HEAT & POWER	HEAT & POWER	HEAT & POWER	HEAT & POWER	HEAT & POWER	HEAT & POWER	POWER ONLY
23	I	REFERENCE TO GENERIC CASES	I, II	III	I, II	I, II	I, II	XIV	XIII-B
24	I	FUEL TYPE	UO2	UO2	UO2	UO2	UO2	GAS	GAS
25	I	REACTOR OR FOSSIL PLANT TYPE	PWR(NP-300)	PWR(NP-300)	CANDU-3	AP-600	CANDU-6	COMBINED CYCLE	COMBINED CYCLE
26	I	SIZE CATEGORY	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM
27	I	WATER PLANT TYPE	MED OR RO	MED/RO HYBRID	MED OR RO	MED OR RO	MED OR RO	MED/RO HYBRID	RO
28	I	SELECTED UNIT NET OUTPUT, MWe (MWt)	300	300	450	600	660	450	450
29	I	TOTAL NET OUTPUT, MWe (MWt)	300	300	450	600	660	450	450
30	I	SERVICE YEAR	2005	2005	2005	2005	2005	2005	2005
31	I	CURRENCY REFERENCE YEAR	1994	1994	1994	1994	1994	1994	1994
32	I	SALEABLE POWER	YES	YES	YES	YES	YES	YES	YES
33	I	ASSUMED AVG COOLING WATER TEMP, C	21	21	21	21	21	21	21
34	I	MED DESIGN COOLING WATER TEMP, C	27	27	27	27	27	27	27
35	I	RO DESIGN COOLING WATER TEMP, C	18	18	18	18	18	18	18
36	I	CONTIGUOUS RO PREHEAT TEMPERATURE, C	18	32	18	18	18	32	18
37	I	SEAWATER TOTAL DISSOLVED SOLIDS, PPM	38500	38500	38500	38500	38500	38500	38500
38	I	PRODUCT DRINKING WATER STANDARD	WHO	WHO	WHO	WHO	WHO	WHO	WHO
40		PERFORMANCE INPUT DATA							
41		BASE POWER PLANT PERFORMANCE DATA:							
42	I	NET THERMAL EFFICIENCY, %	31.6	31.6	29.7	31.0	29.7	50.0	50.0
43	I	BOILER EFFICIENCY, %	N/A	N/A	N/A	N/A	N/A	0.92	0.92
44	I	MAIN STEAM TEMPERATURE, C	293	293	260	271	260	427	427
45	I	MAIN STEAM PRESSURE, BAR	77.8	77.8	46.9	55.9	46.9	81.6	81.6

	A	B	C	D	E	F	G	H	I
46	i	CONDENSER RANGE, C	8	8	8	8	8	8	8
47	i	CONDENSER COOLING WTR PUMP HEAD, BAR	1.7	1.7	1.7	1.7	1.7	1.7	1.7
48	i	CONDENSER COOLING WTR PUMP EFFICIENCY	0.9	0.9	0.9	0.9	0.9	0.9	0.9
49	i	CONDENSING TEMPERATURE, C	37	37	37	37	37	37	37
50	i	PLANNED OUTAGE RATE	0.100	0.100	0.100	0.100	0.100	0.100	0.100
51	i	UNPLANNED OUTAGE RATE	0.110	0.110	0.110	0.110	0.110	0.110	0.110
52									
53		DUAL-PURPOSE PLT PERFORMANCE DATA:							
54		CONDENSING TEMPERATURE, C	66.5	56.5	54.5	51.9	50.5	58.5	N/A
55		INTERMEDIATE LOOP FLASH STM TEMP, C	60	50	48	45.4	44	N/A	N/A
56		INTERMEDIATE LOOP COND. RTRN TEMP, C	58	48	46	43.4	42	N/A	N/A
57	i	INTERMEDIATE LOOP PRESSURE LOSS, BAR	1	1	1	1	1	N/A	N/A
58	i	INTEMEDIATE LOOP PUMP EFFICIENCY	0.9	0.9	0.9	0.9	0.9	N/A	N/A
59									
60		MED WATER PLT PERFORMANCE DATA:							
61	i	DESALINATION TECHNOLOGY	LT-MED	LT-MED	LT-MED	LT-MED	LT-MED	LT-MED	N/A
62	i	PRODUCT WATER TDS, PPM	25	25	25	25	25	25	N/A
63	i	MAXIMUM BRINE TEMPERATURE, C	58	48	46	43.4	42	56	N/A
64		SEAWATER TEMPERATURE, C	27	27	27	27	27	27	N/A
65	i	MED CONDENSER RANGE, C	5	5	5	5	5	5	N/A
66	i	MED CONDENSER APPROACH, C	2	2	2	2	2	2	N/A
67		MINIMUM CONDENSING TEMPERATURE, C	34	34	34	34	34	34	N/A
68		OVERALL MED WORKING TEMPERATURE, C	24	14	12	9	8	22	N/A
69		TEMPERATURE DROP BETWEEN EFFECTS, C	2.15	1.97	1.93	1.88	1.85	2.12	N/A
70		NUMBER OF EFFECTS	12	8	7	6	5	11	N/A
71		GOR, kg PRODUCT/kg STEAM	9.9	7.0	6.3	5.5	4.6	9.2	N/A
72	i	UNIT SIZE, CU.M/D	48,000	24,000	24,000	24,000	24,000	24,000	N/A
73		SEAWATER/PRODUCT FLOW RATIO	10.5	14.7	16.5	18.9	22.3	11.2	N/A
74	i	SEAWATER HEAD + PRESS LOSS, BAR	1.7	1.7	1.7	1.7	1.7	1.7	N/A
75	i	SEAWATER PUMP EFFICIENCY	0.9	0.9	0.9	0.9	0.9	0.9	N/A
76	i	WATER PLANT SPEC. PWR USE kWe/CU.M/D	0.083	0.083	0.083	0.083	0.083	0.083	N/A
77	i	WTR PLT PLANNED OUTAGE RATE	0.030	0.030	0.030	0.030	0.030	0.030	N/A
78	i	WTR PLT UNPLANNED OUTAGE RATE	0.065	0.065	0.065	0.065	0.065	0.065	N/A
79		BACKUP HEAT SOURCE SIZE, MWt	672	657	1076	1341	1567	451	N/A
80	i	BACKUP HEAT SOURCE AVAILABILITY	0.9	0.9	0.9	0.9	0.9	0.9	N/A
81									
82		MEMBRANE WATER PLT PERFORMANCE DATA:							
83	i	NO. STAGES TO MEET WATER STANDARD	1	1	1	1	1	1	1
84		SEAWATER TDS, PPM	38,500	38,500	38,500	38,500	38,500	38,500	38,500
85	i	RO PRODUCT WATER TDS, PPM	270	270	270	270	270	270	270
86		WATER FLUX INCREASE FACTOR FROM TEMP	1	1.1	1	1	1	1.1	1
87		OUTPUT PER UNIT, CU.M/D	24,000	26,400	24,000	24,000	24,000	26,400	24,000
88		RECOVERY RATIO	0.50	0.55	0.50	0.50	0.50	0.5	0.5
89	i	SEAWATER PUMP HEAD, BAR	1.7	1.7	1.7	1.7	1.7	1.7	1.7
90	i	SEAWATER PUMP EFFICIENCY	0.9	0.9	0.9	0.9	0.9	0.9	0.9
91	i	BOOSTER PUMP HEAD, BAR	3.3	3.3	3.3	3.3	3.3	3.3	3.3
92	i	BOOSTER PUMP EFFICIENCY	0.9	0.9	0.9	0.9	0.9	0.9	0.9
93	i	STAGE 1 HIGH HD PUMP PRESS RISE, BAR	82	82	82	82	82	82	82
94	i	STAGE 1 HIGH HEAD PUMP EFFICIENCY	0.85	0.85	0.85	0.85	0.85	0.85	0.85
95	i	STG 1 HYDRAULIC COUPLING EFFICIENCY	0.965	0.965	0.965	0.965	0.965	0.965	0.965

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	A	B	C	D	E	F	G	H	I
96	i	ENERGY RECOVERY EFFICENCY	0.9	0.9	0.9	0.9	0.9	0.9	0.9
97	i	STG 2 HYDRAULIC COUPLING EFFICIENCY	0.965	0.965	0.965	0.965	0.965	0.965	0.965
98	i	STAGE 2 HIGH HD PUMP PRESS RISE, BAR	0	0	0	0	0	0	0
99	i	STAGE 2 HIGH HEAD PUMP EFFICIENCY	0.9	0.9	0.9	0.9	0.9	0.9	0.9
100	i	OTHER SPECIFIC POWER USE, kWe/CU.M/D	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408
101	i	RO PLANT AVAILABILITY	0.91	0.91	0.91	0.91	0.91	0.91	0.91
102									
103		COST INPUT DATA							
104									
105		POWER PLANT COST DATA:							
106	i	SPEC. CONSTR. COST, $/kWe ($/kWt)	2200	2200	2140.41	1672.00	2059.00	600	600
107		ADDITIONL CONSTR. COST, $/kWe ($/kWt)	220	220	214	167	206	60	60
108		TOTAL CONSTR. COST, $/kWe ($/kWt)	2420	2420	2354	1839	2265	660	660
109	i	CONSTRUCTION LEAD TIME, MONTHS	60	60	60	60	60	36	36
110	i	SPECIFIC O&M COST, $/MWeh ($/MWth)	13.09	13.09	11.00	8.80	9.24	5.50	5.50
111	i	GAS PRICE AT STARTUP, $/BOE	N/A	N/A	N/A	N/A	N/A	15.50	15.50
112	i	SPECIFIC FUEL COST, $/MWeh ($/MWth)	13.89	13.89	4.35	10.8	3.8	18.82	18.82
113		LEVELIZED ANNUAL DECOMM. COST, M$	2.11	2.11	3.16	4.21	4.63	0.00	0.00
114	i	FUEL ANNUAL REAL ESCALATION, %	0	0	0	0	0	2	2
115									
116		THERMAL WATER PLANT COST DATA:							
117	i	CORRECTION FACTOR FOR UNIT SIZE	0.9	0.9	0.9	0.9	0.9	0.9	N/A
118	i	BASE UNIT COST, $/CU.M/D	1440	1440	1440	1440	1440	1440	N/A
119		INTERMEDIATE LOOP UNIT COST, $/CU.M/D	111	156	175	201	237	0	N/A
120	i	WATER PLT COST CONTG'CY FACTOR	0.10	0.10	0.10	0.10	0.10	0.10	N/A
121	i	WATER PLT OWNERS COST FACTOR	0.05	0.05	0.05	0.05	0.05	0.05	N/A
122	i	WATER PLT LEAD TIME,MONTHS	36	36	36	36	36	36	N/A
123	i	AVERAGE MANAGEMENT SALARY, $/YR	66000	66000	66000	66000	66000	66000	N/A
124	i	AVERAGE LABOR SALARY, $/YR	29700	29700	29700	29700	29700	29700	N/A
125	i	SPECIFIC O&M SPARE PARTS COST, $/CU.M	0.04	0.04	0.04	0.04	0.04	0.04	N/A
126	i	SPECIFIC O&M CHEM COST, $/CU.M	0.02	0.02	0.02	0.02	0.02	0.02	N/A
127	i	WATER PLT O&M INS COST,% BASE CAP	0.50	0.50	0.50	0.50	0.50	0.50	N/A
128	i	BACKUP HEAT SOURCE UNIT COST, $/MWt	55000	55000	55000	55000	55000	55000	N/A
129									
130		MEMBRANE WATER PLANT COST DATA:							
131	i	BASE UNIT COST, $/CU.M/D	1125	1023	1125	1125	1125	1023	1125
132	i	WATER PLT COST CONTG'CY FACTOR	0.10	0.10	0.10	0.10	0.10	0.10	0.10
133	i	WATER PLT OWNERS COST FACTOR	0.05	0.05	0.05	0.05	0.05	0.05	0.05
134	i	WATER PLT LEAD TIME,MONTHS	30	24	30	30	30	24	30
135	i	AVERAGE MANAGEMENT SALARY, $/YR	66000	66000	66000	66000	66000	66000	66000
136	i	AVERAGE LABOR SALARY, $/YR	29700	29700	29700	29700	29700	29700	29700
137	i	O&M MEMBRANE REPLACEMENT COST, $/CU.M	0.12	0.11	0.12	0.12	0.12	0.11	0.12
138	i	O&M SPARE PARTS COST, $/CU.M	0.03	0.03	0.03	0.03	0.03	0.03	0.03
139	i	SPECIFIC CHEMICAL COST, $/CU.M	0.07	0.06	0.07	0.07	0.07	0.06	0.07
140	i	WATER PLT O&M INS COST,% BASE CAP	0.50	0.50	0.50	0.50	0.50	0.50	0.50
141									
142		ECONOMIC PARAMETERS INPUT DATA							
143									
144		CASE 1: 5% INTEREST RATE							
145	i	AFUDC RATE, %/YR	5.00	5.00	5.00	5.00	5.00	5.00	5.00

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	A	B	C	D	E	F	G	H	I
146		LN-94$ FIXED CHARGE RATE, %	6.51	6.51	6.51	6.51	6.51	6.51	6.51
147	i	PURCHASED ELECTRICITY COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A
148									
149		CASE 2: 8% INTEREST RATE							
150	i	AFUDC RATE, %/YR	8.00	8.00	8.00	8.00	8.00	8.00	8.00
151		LN-94$ FIXED CHARGE RATE, %	8.88	8.88	8.88	8.88	8.88	8.88	8.88
152	i	PURCHASED ELECTRICITY COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A
153									
154		CASE 3: 10% INTEREST RATE							
155	i	AFUDC RATE, %/YR	10.00	10.00	10.00	10.00	10.00	10.00	10.00
156		LN-94$ FIXED CHARGE RATE, %	10.61	10.61	10.61	10.61	10.61	10.61	10.61
157	i	PURCHASED ELECTRICITY COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A
158									
159		PERFORMANCE CALCULATIONS							
160									
161		SINGLE-PURPOSE PLT PERFORMANCE:							
162		THERMAL POWER, MWt	949	949	1515	1935	2222	900	900
163		PLANT GROSS OUTPUT, MWe	316	316	474	632	695	474	474
164		PLANT AUX LOADS, MWe	15.8	15.8	23.7	31.6	34.7	23.7	23.7
165		CONDENSER COOLING WTR FLOW, kg/s	19391	19391	31807	39879	46650	11997	N/A
166		CONDENSER COOLING WTR PUMP POWER, MWe	3.87	3.87	6.34	7.95	9.30	2.39	N/A
167		REJECT HEAT LOAD, MWt	633.6	633.6	1041.5	1303.9	1527.5	426.3	N/A
168		TURBINE EXHAUST FLOW, kg/s	275.5	275.5	452.8	566.9	664.1	185.4	N/A
169		OPERATING AVAILABILITY	0.801	0.801	0.801	0.801	0.801	0.801	0.801
170									
171		DUAL-PURPOSE POWER PLANT PERFORMANCE:							
172		LOST SHAFTWORK, MWs	38.4	23.3	34.5	36.9	39.2	24.9	N/A
173		LOST ELECTRICITY PRODUCTION, MWe	38.1	23.1	34.2	36.6	38.9	24.6	N/A
174		NET ELECTRICITY PRODUCED, MWe	261.9	276.9	415.8	563.4	621.1	425.4	N/A
175		TOTAL HEAT TO WTR PLT, MWt	672	657	1076	1341	1567	451	N/A
176		BACKPRESSURE TURB. EXHAUST FLOW, kg/s	292.2	285.6	467.8	583.0	681.2	196.2	N/A
177		INTERMEDIATE LOOP FLOW RATE, kg/s	80380	78577	128704	160383	187406	N/A	N/A
178		INTERMEDIATE LOOP PUMPING POWER, MWe	9.43	9.22	15.10	18.81	21.99	N/A	N/A
179		FLASH STEAM FLOW TO MED, kg/s	290	283	464	578	675	194	N/A
180									
181		THERMAL WATER PLANT PERFORMANCE:							
182		MAXIMUM WATER PLT CAPACITY, CU.M/DAY	247246	172304	251184	272928	270382	154722	N/A
183		NUMBER OF UNITS	6	8	11	12	12	7	N/A
184		SEAWATER FLOW, kg/s	29,978	29,306	48,001	59,816	69,894	20,128	N/A
185		INCREMENTAL SEAWATER PUMPING PWR, MWe	2.11	1.98	3.23	3.98	4.64	1.62	N/A
186		WATER PLANT INTERNAL POWER USE, MWe	20.52	14.30	20.85	22.65	22.44	12.84	N/A
187		WTR PLT+INT.LOOP+SEAWTR PUMP PWR, MWe	32.06	25.50	39.18	45.44	49.06	14.46	N/A
188		WTR PLT OPERATING AVAILABILITY	0.907	0.907	0.907	0.907	0.907	0.907	N/A
189		COMBINED HEAT SOURCE AVAILABILITY	0.98	0.98	0.98	0.98	0.98	0.98	N/A
190		COMBINED PWR/WTR PLT CAPACITY FACTOR	0.889	0.889	0.889	0.889	0.889	0.889	N/A
191		ANNUAL WATER PRODUCTION, CU.M/YR	80,218,740	55,903,849	81,496,380	88,551,393	87,725,151	50,199,480	N/A
192		AVRG DAILY WATER PRODUCTION, CU.M/D	219,777	153,161	223,278	242,607	240,343	137,533	N/A
193									
194		RO WATER PLANT PERFORMANCE:							
195		PRODUCTION CAPACITY, CU.M/DAY	247,246	67,696	251,184	272,928	270,382	85,278	240,000

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	A	B	C	D	E	F	G	H	I
196		NUMBER OF RO UNITS	11	3	11	12	12	4	11
197		SEAWATER FLOW, kg/s	5723	1425	5814	6318	6259	1974	5556
198		STAND-ALONE SEAWATER PUMPING PWR, MWe	1.14	N/A	1.16	1.26	1.25	N/A	1.11
199		CONTIGUOUS SEAWATER PUMPING PWR, MWe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
200		BOOSTER PUMP POWER, MWe	2.22	0.55	2.25	2.45	2.42	0.76	2.15
201		STAGE 1 HIGH HEAD PUMP POWER, MWe	60.41	15.04	61.37	66.68	66.06	20.84	58.64
202		ENERGY RECOVERY, MWe	21.41	4.80	21.75	23.63	23.41	7.38	20.78
203		STAGE 2 HIGH HEAD PUMP POWER, MWe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
204		OTHER POWER, MWe	10.09	2.51	10.25	11.14	11.03	3.16	9.79
205		TOTAL STAND-ALONE POWER USE, MWe	52.45	N/A	53.28	57.90	57.36	N/A	50.91
206		TOTAL CONTIGUOUS POWER USE, MWe	51.31	13.30	52.12	56.64	56.11	17.38	49.80
207		ANNUAL AVG. WATER PRODUCTION, CU.M/YR	82,122,752	22,485,259	83,430,717	90,653,182	89,807,330	28,325,023	79,716,000
208		AVG. DAILY WATER PRODUCTION, CU.M/DAY	224,994	61,603	228,577	248,365	246,047	77,603	218,400
209		SPEC. (S-A) PWR CONSUMPTION, kWh/CU.M	5.09	N/A	5.09	5.09	5.09	N/A	5.09
210		SPEC.(CONT) PWR CONSUMPTION, kWh/CU M	4.98	4.72	4.98	4.98	4.98	4.89	4.98
211		NET PWR PLNT SALEABLE PWR (S-A), MWe	247.55	N/A	396.72	542.10	602.64	N/A	399.09
212		NET PWR PLNT SALEABLE PWR (CONT), MWe	248.69	N/A	397.88	543.36	603.89	N/A	400.20
213									
214		COST CALCULATIONS							
215									
216		THERMAL WATER PLANT COSTS:							
217		NUMBER OF UNITS	6	8	11	12	12	7	N/A
218		CORRECTION FACTOR FOR NO. OF UNITS	0.888	0.844	0.782	0.763	0.763	0.866	N/A
219		WATER PLT SPECIFIC BASE COST,$/CU M/D	1151	1094	1014	988	988	1122	N/A
220		INC. IN/OUTFALL SPEC. BS CT, $/CU.M/D	50	68	62	64	71	73	N/A
221		INTERMEDIATE LOOP COST, $/CU.M/D	111	156	175	201	237	0	N/A
222		TOTAL SPECIFIC BASE COST, $/CU.M/D	1313	1318	1252	1254	1297	1195	N/A
223		NUMBER OF MANAGEMENT PERSONNEL	9	8	9	9	9	7	N/A
224		WATER PLT O&M MGMT COST,M$/Y	0.59	0.53	0.59	0.59	0.59	0.46	N/A
225		NUMBER OF LABOR PERSONNEL	47	40	47	49	48	39	N/A
226		WATER PLT O&M LABOR COST,M$/Y	1.39	1.20	1.40	1.44	1.44	1.15	N/A
227		WATER PLT ADJUSTED BASE COST,M$	324.56	227.10	314.36	342.28	350.70	184.97	N/A
228		BACKUP HEAT SOURCE BASE COST, M$	36.96	36.13	59.18	73.74	86.17	24.82	N/A
229		TOTAL WATER PLANT BASE COST, M$	361.52	263.23	373.54	416.03	436.87	209.78	N/A
230		WATER PLT OWNERS COST,M$	18.08	13.16	18.68	20.80	21.84	10.49	N/A
231		WATER PLT CONTINGENCY ,M$	37.96	27.64	39.22	43.68	45.87	22.03	N/A
232		WATER PLT TOT CONSTRUCTION COST ,M$	417.56	304.03	431.44	480.51	504.58	242.30	N/A
233		WATER PLT O&M COST,M$/YR	8.42	6.22	8.45	9.06	9.05	5.55	N/A
234									
235		RO WATER PLANT COSTS:							
236		NUMBER OF UNITS	11	3	11	12	12	4	11
237		CORRECTION FACTOR FOR NO. OF UNITS	0.782	0.959	0.782	0.763	0.763	0.935	0.782
238		PROCESS PLT SPECIFIC COST,$/CU.M/D	880	981	880	858	858	956	880
239		STND-ALN IN/OUTFALL SPEC.CT, $/CU.M/D	81	N/A	80	77	78	N/A	82
240		STND-ALN WTR PLNT SPEC. CT, $/CU.M/D	961	N/A	960	935	936	N/A	962
241		NUMBER OF MANAGEMENT PERSONNEL	9	5	9	9	9	5	9
242		O&M MGMT COST,M$/Y	0.59	0.33	0.59	0.59	0.59	0.33	0.59
243		NUMBER OF LABOR PERSONNEL	47	25	47	49	48	28	46
244		O&M LABOR COST,M$/Y	1.39	0.75	1.40	1.44	1.44	0.82	1.37
245		STND-ALN WTR PLT ADJUSTED BASE CT,M$	237.52	N/A	241.18	255.32	253.01	N/A	230.79

	A	B	C	D	E	F	G	H	I
246		CONTIGUOUS WTR PLT ADJUSTED BS CT,M$	217.61	66.38	221.07	234.18	232.00	81.52	211.23
247		WATER PLT OWNERS COST,M$	11.88	3.32	12.06	12.77	12.65	4.08	11.54
248		WATER PLT CONTINGENCY ,M$	24.94	6.97	25.32	26.81	26.57	8.56	24.23
249		STND-ALN WTR PLT TOT CONSTRUCT CT, M$	274.34	N/A	278.56	294.89	292.23	N/A	266.57
250		CONTIGUOUS WTR PLT TOT CONSTR CT, M$	254.42	76.67	258.46	273.76	271.21	94.16	247.00
251		WATER PLT O&M COST,M$/YR	21.24	5.91	21.55	23.26	23.06	7.23	20.66
252									
253		ECONOMIC EVALUATIONS							
254									
255		CASE 1: 5% INTEREST RATE							
256		-POWER PLANT COST							
257		TOTAL CONSTRUCTION COST, M$	726.00	726.00	1059.51	1103.52	1494.83	297.00	297.00
258		AFUDC, M$	94.18	94.18	137.45	143.16	193.92	22.55	22.55
259		TOTAL PLANT INVESTMENT, M$	820.18	820.18	1196.95	1246.68	1688.75	319.55	319.55
260		LEVELIZED ANNUAL CAPITAL COST, M$	53.35	53.35	77.86	81.10	109.86	20.79	20.79
261		FUEL LEVELIZED FACTOR	1.00	1.00	1.00	1.00	1.00	1.60	1.60
262		ANNUAL FUEL COST, M$	29.24	29.24	13.74	45.47	17.60	94.93	94.93
263		ANNUAL O&M COST, M$	27.55	27.55	34.73	37.05	42.79	17.37	17.37
264		ELEC. PWR COST (HEAT ONLY), M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
265		DECOMMISSIONING COST, M$	2.11	2.11	3.16	4.21	4.63	0.00	0.00
266		TOTAL ANNUAL REQUIRED REVENUE, M$	112.25	112.25	129.49	167.83	174.88	133.09	133.09
267		ANNUAL ELECTRICITY PRODUCTION, kWh	2,105,028,000	2,105,028,000	3,157,542,000	4,210,056,000	4,631,061,600	3,157,542,000	3,157,542,000
268		LEVELIZED POWER COST, $/kWh	0.053	0.053	0.041	0.040	0.038	0.042	0.042
269									
270		-THERMAL (MED) PLANT:							
271		ANNUAL WATER PROD, CU.M/YR	80,218,740	55,903,849	81,496,380	88,551,393	87,725,151	50,199,480	N/A
272		TOTAL CONSTRUCTION COST, M$	417.56	304.03	431.44	480.51	504.58	242.30	N/A
273		AFUDC ,M$	31.70	23.09	32.76	36.49	38.31	18.40	N/A
274		TOTAL INVESTMENT ,M$	449.26	327.12	464.20	517.00	542.89	260.70	N/A
275		WATER CT, FIXED CHARGE, M$/YR	29.23	21.28	30.20	33.63	35.32	16.96	N/A
276		WATER CT, HEAT CHARGE, M$/YR	15.80	9.60	10.92	11.35	11.43	8.09	N/A
277		WATER CT, ELEC CHARGE, M$/YR	13.31	10.59	12.51	14.11	14.43	4.75	N/A
278		WATER CT, O&M CHARGE, M$/YR	8.42	6.22	8.45	9.06	9.05	5.55	N/A
279		TOTAL WATER COST, $/CU.M	0.83	0.85	0.76	0.77	0.80	0.70	N/A
280									
281		-STAND-ALONE RO PLANT:							
282		SPECIFIED OUTPUT							
283		ANNUAL WATER PROD, CU.M/YR	82,122,752	N/A	83,430,717	90,653,182	89,807,330	N/A	79,716,000
284		TOTAL CONSTRUCTION COST ,M$	274.34	N/A	278.56	294.89	292.23	N/A	266.57
285		AFUDC ,M$	17.25	N/A	17.52	18.54	18.38	N/A	16.76
286		TOTAL INVESTMENT ,M$	291.59	N/A	296.08	313.43	310.61	N/A	283.33
287		WATER CT, FIXED CHARGE, M$/YR	18.97	N/A	19.26	20.39	20.21	N/A	18.43
288		WATER CT, ELEC CHARGE, M$/YR	22.30	N/A	17.42	18.40	17.27	N/A	17.11
289		WATER CT, O&M CHARGE, M$/YR	21.24	N/A	21.55	23.26	23.06	N/A	20.66
290		TOTAL WATER COST, $/CU.M	0.76	N/A	0.70	0.68	0.67	N/A	0.70
291		-CONTIGUOUS RO PLANT:							
292		ANNUAL WATER PROD, CU.M/YR	82,122,752	22,485,259	83,430,717	90,653,182	89,807,330	28,325,023	79,716,000
293		TOTAL CONSTRUCTION COST ,M$	254.42	76.67	258.46	273.76	271.21	94.16	247.00
294		AFUDC ,M$	16.00	3.83	16.25	17.22	17.06	4.71	15.53
295		TOTAL INVESTMENT ,M$	270.42	80.50	274.71	290.97	288.27	98.86	262.54

	A	B	C	D	E	F	G	H	I
296		WATER CT, FIXED CHARGE, M$/YR	17.59	5.24	17.87	18.93	18.75	6.43	17.08
297		WATER CT, ELEC CHARGE, M$/YR	21.81	5.66	17.04	18.00	16.89	5.84	16.73
298		WATER CT, O&M CHARGE, M$/YR	21.24	5.91	21.55	23.26	23.06	7.23	20.66
299		TOTAL WATER COST, $/CU.M	0.74	0.75	0.68	0.66	0.65	0.69	0.68
300									
301		HYBRID MED/RO							
302		HYBRID ANNUAL WATER PRODUCTION	N/A	78,389,108	N/A	N/A	N/A	78,524,503	N/A
303		COMBINED WTR COST FOR HYBRID, $/CU.M	N/A	0.82	N/A	N/A	N/A	0.70	N/A
304									
305		CASE 2: 8% INTEREST RATE							
306		-POWER PLANT COST							
307		TOTAL CONSTRUCTION COST, M$	726.00	726.00	1059.51	1103.52	1494.83	297.00	297.00
308		AFUDC, M$	154.03	154.03	224.78	234.12	317.14	36.34	36.34
309		TOTAL PLANT INVESTMENT, M$	880.03	880.03	1284.29	1337.64	1811.98	333.34	333.34
310		LEVELIZED ANNUAL CAPITAL COST, M$	78.17	78.17	114.08	118.82	160.95	29.61	29.61
311		FUEL LEVELIZED FACTOR	1.00	1.00	1.00	1.00	1.00	1.54	1.54
312		ANNUAL FUEL COST, M$	29.24	29.24	13.74	45.47	17.60	91.49	91.49
313		ANNUAL O&M COST, M$	27.55	27.55	34.73	37.05	42.79	17.37	17.37
314		DECOMMISSIONING COST, M$	2.11	2.11	3.16	4.21	4.63	0.00	0.00
315		ELECTRIC POWER COST (HEATONLY), M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A
316		TOTAL ANNUAL REQUIRED REVENUE, M$	137.07	137.07	165.71	205.55	225.97	138.47	138.47
317		ANNUAL ELECTRICITY PRODUCTION, KWH	2,105,028,000	2,105,028,000	3,157,542,000	4,210,056,000	4,631,061,600	3,157,542,000	3,157,542,000
318		LEVELIZED POWER COST, $/kWh	0.065	0.065	0.052	0.049	0.049	0.044	0.044
319									
320		-THERMAL (MED) PLANT:							
321		TOTAL CONSTRUCTION COST, M$	417.56	304.03	431.44	480.51	504.58	242.30	N/A
322		AFUDC, M$	51.10	37.20	52.80	58.80	61.74	29.65	N/A
323		TOTAL WATER PLANT INVESTMENT, M$	468.65	341.23	484.24	539.31	566.33	271.95	N/A
324		WATER CT, FIXED CHARGE, M$/YR	41.63	30.31	43.01	47.91	50.31	24.16	N/A
325		WATER CT, HEAT CHARGE, M$/YR	19.30	11.72	13.97	13.90	14.77	8.42	N/A
326		WATER CT, ELEC CHARGE, M$/YR	16.26	12.93	16.01	17.28	18.64	4.94	N/A
327		WATER CT, O&M CHARGE, M$/YR	8.42	6.22	8.45	9.06	9.05	5.55	N/A
328		TOTAL WATER COST, $/CU.M	1.07	1.09	1.00	1.00	1.06	0.86	N/A
329									
330		-STAND-ALONE RO PLANT:							
331		TOTAL CONSTRUCTION COST ,M$	274.34	N/A	278.56	294.89	292.23	N/A	266.57
332		AFUDC ,M$	27.70	N/A	28.13	29.78	29.51	N/A	26.92
333		TOTAL INVESTMENT ,M$	302.04	N/A	306.69	324.67	321.74	N/A	293.49
334		WATER CT, FIXED CHARGE, M$/YR	26.83	N/A	27.24	28.84	28.58	N/A	26.07
335		WATER CT, ELEC CHARGE, M$/YR	27.22	N/A	22.29	22.53	22.31	N/A	17.80
336		WATER CT, O&M CHARGE, M$/YR	21.24	N/A	21.55	23.26	23.06	N/A	20.66
337		TOTAL WATER COST, $/CU.M	0.92	N/A	0.85	0.82	0.82	N/A	0.81
338		-CONTIGUOUS RO PLANT:							
339		TOTAL CONSTRUCTION COST ,M$	254.42	76.67	258.46	273.76	271.21	94.16	247.00
340		AFUDC ,M$	25.69	6.13	26.10	27.64	27.39	7.53	24.94
341		TOTAL INVESTMENT ,M$	280.12	82.80	284.56	301.40	298.60	101.69	271.95
342		WATER CT, FIXED CHARGE, M$/YR	24.88	7.36	25.28	26.77	26.52	9.03	24.16
343		WATER CT, ELEC CHARGE, M$/YR	26.63	6.91	21.81	22.04	21.82	6.08	17.41
344		WATER CT, O&M CHARGE, M$/YR	21.24	5.91	21.55	23.26	23.06	7.23	20.66
345		TOTAL WATER COST, $/CU.M	0.89	0.90	0.82	0.80	0.80	0.79	0.78

	A	B	C	D	E	F	G	H	I
346									
347		HYBRID MED/RO							
348		HYBRID ANNUAL WATER PRODUCTION	N/A	78,389,108	N/A	N/A	N/A	78,524,503	N/A
349		COMBINED WTR COST FOR HYBRID, $/CU.M	N/A	1.04	N/A	N/A	N/A	0.83	N/A
350									
351		CASE 3: 10% INTEREST RATE							
352		-POWER PLANT COST							
353		TOTAL CONSTRUCTION COST, M$	726.00	726.00	1059.51	1103.52	1494.83	297.00	297.00
354		AFUDC, M$	195.34	195.34	285.07	296.91	402.20	45.65	45.65
355		TOTAL PLANT INVESTMENT, M$	921.34	921.34	1344.57	1400.43	1897.03	342.65	342.65
356		LEVELIZED ANNUAL CAPITAL COST, M$	97.73	97.73	142.63	148.56	201.24	36.35	36.35
357		FUEL LEVELIZED FACTOR	1.00	1.00	1.00	1.00	1.00	1.51	1.51
358		ANNUAL FUEL COST, M$	29.24	29.24	13.74	45.47	17.60	89.56	89.56
359		ANNUAL O&M COST, M$	27.55	27.55	34.73	37.05	42.79	17.37	17.37
360		DECOMMISSIONING COST, M$	2.11	2.11	3.16	4.21	4.63	0.00	0.00
361		ELEC. PWR COST (HEAT ONLY), M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
362		TOTAL ANNUAL REQUIRED REVENUE, M$	156.63	156.63	194.26	235.28	266.26	143.28	143.28
363		ANNUAL ELECTRICITY PRODUCTION, KWH	2,105,028,000	2,105,028,000	3,157,542,000	4,210,056,000	4,631,061,600	3,157,542,000	3,157,542,000
364		LEVELIZED POWER COST, $/kWh	0.074	0.074	0.062	0.056	0.057	0.045	0.045
365									
366		-THERMAL (MED) PLANT:							
367		TOTAL CONSTRUCTION COST	417.56	304.03	431.44	480.51	504.58	242.30	N/A
368		AFUDC ,M$	64.17	46.73	66.31	73.85	77.55	37.24	N/A
369		TOTAL INVESTMENT ,M$	481.73	350.76	497.75	554.36	582.13	279.54	N/A
370		WATER CT, FIXED CHARGE, M$/YR	51.10	37.21	52.80	58.81	61.75	29.65	N/A
371		WATER CT, HEAT CHARGE, M$/YR	22.05	13.39	16.38	15.91	17.40	8.71	N/A
372		WATER CT, ELEC CHARGE, M$/YR	18.58	14.77	18.77	19.78	21.96	5.11	N/A
373		WATER CT, O&M CHARGE, M$/YR	8.42	6.22	8.45	9.06	9.05	5.55	N/A
374		TOTAL WATER COST, $/CU.M	1.25	1.28	1.18	1.17	1.26	0.98	N/A
375									
376		-STAND-ALONE RO PLANT:							
377		TOTAL CONSTRUCTION COST, M$	274.34	N/A	278.56	294.89	292.23	N/A	266.57
378		AFUDC, M$	34.71	N/A	35.25	37.31	36.97	N/A	33.73
379		TOTAL INVESTMENT ,M$	309.05	N/A	313.81	332.20	329.20	N/A	300.30
380		WATER CT, FIXED CHARGE, M$/YR	32.78	N/A	33.29	35.24	34.92	N/A	31.86
381		WATER CT, ELEC CHARGE, M$/YR	31.11	N/A	26.13	25.79	26.29	N/A	18.42
382		WATER CT, O&M CHARGE, M$/YR	21.24	N/A	21.55	23.26	23.06	N/A	20.66
383		TOTAL WATER COST, $/CU.M	1.04	N/A	0.97	0.93	0.94	N/A	0.89
384		-CONTIGUOUS RO PLANT:							
385		TOTAL CONSTRUCTION COST, M$	254.42	76.67	258.46	273.76	271.21	94.16	247.00
386		AFUDC, M$	32.19	7.67	32.70	34.64	34.32	9.42	31.25
387		TOTAL INVESTMENT ,M$	286.61	84.34	291.16	308.39	305.53	103.57	278.26
388		WATER CT, FIXED CHARGE, M$/YR	30.40	8.95	30.89	32.71	32.41	10.99	29.52
389		WATER CT, ELEC CHARGE, M$/YR	30.43	7.89	25.56	25.23	25.71	6.29	18.01
390		WATER CT, O&M CHARGE, M$/YR	21.24	5.91	21.55	23.26	23.06	7.23	20.66
391		TOTAL WATER COST, $/CU.M	1.00	1.01	0.93	0.90	0.90	0.86	0.86
392									
393		HYBRID MED/RO							
394		HYBRID ANNUAL WATER PRODUCTION	N/A	78,389,108	N/A	N/A	N/A	78,524,503	N/A
395		COMBINED WTR COST FOR HYBRID, $/CU.M	N/A	1.20	N/A	N/A	N/A	0.94	N/A

EGYPT.XLS

	A	B	C	D	E	F	G	H	I
396									
397		SUMMARY							
398									
399		CASE	Egypt-1	Egypt-2	Egypt-3	Egypt-4	Egypt-5	Egypt-6	Egypt-7
400		PLANT TYPE	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	FOSSIL	FOSSIL
401		PRODUCT	HEAT & POWER	HEAT & POWER	HEAT & POWER	HEAT & POWER	HEAT & POWER	HEAT & POWER	POWER ONLY
402		REFERENCE OF FLOW DIAGRAM	I, II	III	I, II	I, II	I, II	XV	XIV
403		WATER PLANT TYPE	MED OR RO	MED/RO HYBRID	MED OR RO	MED OR RO	MED OR RO	MED/RO HYBRID	RO
404		REACTOR TYPE	PWR(NP-300)	PWR(NP-300)	CANDU-3	AP-600	CANDU-6	COMBINED CYCLE	COMBINED CYCLE
405		SELECTED NET OUTPUT, MWe (MWt)	300	300	450	600	660	450	450
406		PRODUCT DRINKING WATER STANDARD	WHO	WHO	WHO	WHO	WHO	WHO	WHO
407									
408		SUMMARY CASE 1: 5% INT & AFUDC RATE							
409		-LEVELIZED POWER COST, $/kWh	0.053	0.053	0.041	0.040	0.038	0.042	0.042
410		-PURCHASED POWER COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A
411		-THERMAL MED PLANT (OPTIMIZED)							
412		WATER PRODUCTION CAPACITY, CU.M/D	247246	172304	251184	272928	270382	154722	N/A
413		NET SALEABLE POWER, MWe	229.88	N/A	376.64	518.00	572.06	N/A	N/A
414		WATER COST, $/CU.M	0.83	0.85	0.76	0.77	0.80	0.70	N/A
415		-STAND-ALONE RO PLT (MED EQ. OUTPUT)							
416		WATER PRODUCTION CAPACITY, CU.M/D	247246	N/A	251184	272928	270382	N/A	240000
417		NET SALEABLE POWER, MWe	247.55	N/A	396.72	542.10	602.64	N/A	399.09
418		WATER COST, $/CU.M	0.76	N/A	0.70	0.68	0.67	N/A	0.70
419		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)							
420		WATER PRODUCTION CAPACITY, CU.M/D	247246	67696	251184	272928	270382	85278	240000
421		NET SALEABLE POWER, MWe	248.69	N/A	397.88	543.36	603.89	N/A	400.20
422		WATER COST, $/CU.M	0.74	0.75	0.68	0.66	0.65	0.69	0.68
423		-HYBRID COMBINED MED/RO							
424		WATER PRODUCTION CAPACITY, CU.M/D	N/A	240000	N/A	N/A	N/A	240000	
425		NET SALEABLE POWER, MWe	N/A	238	N/A	N/A	N/A	394	N/A
426		WATER COST, $/CU.M	N/A	0.82	N/A	N/A	N/A	0.70	N/A
427									
428		SUMMARY CASE 2: 8% INT & AFUDC RATE							
429		-LEVELIZED POWER COST, $/kWh	0.065	0.065	0.052	0.049	0.049	0.044	0.044
430		-PURCHASED POWER COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A
431		-THERMAL MED PLANT (OPTIMIZED)							
432		WATER PRODUCTION CAPACITY, CU.M/D	247246	172304	251184	272928	270382	154722	N/A
433		NET SALEABLE POWER, MWe	229.88	N/A	376.64	518.00	572.06	N/A	N/A
434		WATER COST, $/CU.M	1.07	1.09	1.00	1.00	1.06	0.86	N/A
435		-STAND-ALONE RO PLT (MED EQ. OUTPUT)							
436		WATER PRODUCTION CAPACITY, CU.M/D	247246	N/A	251184	272928	270382	N/A	240000
437		NET SALEABLE POWER, MWe	247.55	N/A	396.72	542.10	602.64	N/A	399.09
438		WATER COST, $/CU.M	0.92	N/A	0.85	0.82	0.82	N/A	0.81
439		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)							
440		WATER PRODUCTION CAPACITY, CU.M/D	247246	67696	251184	272928	270382	85278	240000
441		NET SALEABLE POWER, MWe	248.69	N/A	397.88	543.36	603.89	N/A	400.20
442		WATER COST, $/CU.M	0.89	0.90	0.82	0.80	0.80	0.79	0.78
443		-HYBRID COMBINED MED/RO							
444		WATER PRODUCTION CAPACITY, CU.M/D	N/A	240000	N/A	N/A	N/A	240000	N/A
445		NET SALEABLE POWER, MWe	N/A	238	N/A	N/A	N/A	394	N/A

	A / B	C	D	E	F	G	H	I
446	WATER COST, $/CU.M	N/A	1.04	N/A	N/A	N/A	0.83	N/A
447								
448	SUMMARY CASE 3: 10% INT & AFUDC RATE							
449	-LEVELIZED POWER COST, $/kWh	0.074	0.074	0.062	0.056	0.057	0.045	0.045
450	-PURCHASED POWER COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A
451	-THERMAL MED PLANT (OPTIMIZED)							
452	WATER PRODUCTION CAPACITY, CU.M/D	247246	172304	251184	272928	270382	154722	N/A
453	NET SALEABLE POWER, MWe	229.88	N/A	376.64	518.00	572.06	N/A	N/A
454	WATER COST, $/CU.M	1.25	1.28	1.18	1.17	1.26	0.98	N/A
455	-STAND ALONE RO PLT (MED EQ. OUTPUT)							
456	WATER PRODUCTION CAPACITY, CU.M/D	247246	N/A	251184	272928	270382	N/A	240000
457	NET SALEABLE POWER, MWe	247.55	N/A	396.72	542.10	602.64	N/A	399.09
458	WATER COST, $/CU.M	1.04	N/A	0.97	0.93	0.94	N/A	0.89
459	-CONTIGUOUS RO PLT (MED EQ. OUTPUT)							
460	WATER PRODUCTION CAPACITY, CU.M/D	247246	67696	251184	272928	270382	85278	240000
461	NET SALEABLE POWER, MWe	248.69	N/A	397.88	543.36	603.89	N/A	400.20
462	WATER COST, $/CU.M	1.00	1.01	0.93	0.90	0.90	0.86	0.86
463	-HYBRID COMBINED MED/RO							
464	WATER PRODUCTION CAPACITY, CU.M/D	N/A	240000	N/A	N/A	N/A	240000	N/A
465	NET SALEABLE POWER, MWe	N/A	238	N/A	N/A	N/A	394	N/A
466	WATER COST, $/CU.M	N/A	1.20	N/A	N/A	N/A	0.94	N/A
467								
468	INVESTMENT COSTS: 8% INTEREST RATE							
469								
470	POWER PLANT							
471	SPECIFIC CONSTRUCTION COST, $/kW	2420	2420	2354	1839	2265	660	660
472	- POWER PLANT CONSTRUCTION, M$	726	726	1060	1104	1495	297	297
473	- POWER PLANT IDC, M$	154	154	225	234	317	36	36
474	TOTAL INVESTMENT COST, M$	880	880	1284	1338	1812	333	333
475	SPECIFIC INVESTMENT COST, $/kW	2933	2933	2854	2229	2745	741	741
476								
477	POWER & THERMAL MED PLANT							
478	- POWER PLANT CONSTRUCTION, M$	726	726	1060	1104	1495	297	N/A
479	- POWER PLANT IDC, M$	154	154	225	234	317	36	N/A
480	-PWR PLT COST PORTION OF WTR PROD M$	206	182	209	183	241	42	N/A
481	- MED PLANT CONSTRUCTION, M$	418	304	431	481	505	242	N/A
482	- MED PLANT IDC, M$	51	37	53	59	62	30	N/A
483	TOTAL INVESTMENT COST, M$	674	523	694	722	808	314	N/A
484	- MED CAPACITY, CU.M/D	247246	172304	251184	272928	270382	154722	N/A
485	SPECIFIC INVESTMENT COST, $/CU.M/D	2727	3035	2761	2646	2987	2028	N/A
486								
487	POWER & S-A RO (MED EQUIV.) PLANT							
488	- POWER PLANT CONSTRUCTION, M$	726	N/A	1060	1104	1495	N/A	297
489	- POWER PLANT IDC, M$	154	N/A	225	234	317	N/A	36
490	-PWR PLT COST PORTION OF WTR PROD M$	154	N/A	152	129	157	N/A	38
491	- RO PLANT CONSTRUCTION, M$	274	N/A	279	295	292	N/A	267
492	- RO PLANT IDC, M$	28	N/A	28	30	30	N/A	27
493	TOTAL INVESTMENT COST, M$	456	N/A	459	454	479	N/A	331
494	- RO (MED EQUIV.) CAPACITY, CU.M/D	247246	N/A	251184	272928	270382	N/A	240000
495	SPECIFIC INVESTMENT COST, $/CU M/D	1844	N/A	1826	1662	1772	N/A	1380

EGYPT.XLS

	A	B	C	D	E	F	G	H	I
496									
497		COST SUMMARY: 8% INTEREST RATE							
498									
499		-POWER PLANT COST							
500		TOTAL PLANT INVESTMENT, M$	880.03	880.03	1284.29	1337.64	1811.98	333.34	333.34
501		LEVELIZED ANNUAL CAPITAL COST, M$	78.17	78.17	114.08	118.82	160.95	29.61	29.61
502		TOTAL ANNUAL REQUIRED REVENUE, M$	137.07	137.07	165.71	205.55	225.97	138.47	138.47
503		LEVELIZED POWER COST, $/kWh	0.065	0.065	0.052	0.049	0.049	0.044	0.044
504									
505		-THERMAL (MED) PLANT:							
506		TOTAL WATER PLANT INVESTMENT, M$	468.65	341.23	484.24	539.31	566.33	271.95	N/A
507		WATER CT, FIXED CHARGE, $/CU.M	0.52	0.54	0.53	0.54	0.57	0.48	N/A
508		WATER CT, ENERGY CHARGE, $/CU.M	0.44	0.44	0.37	0.35	0.38	0.27	N/A
509		WATER CT, O&M CHARGE, $/CU.M	0.10	0.11	0.10	0.10	0.10	0.11	N/A
510		TOTAL WATER COST, $/CU.M	1.07	1.09	1.00	1.00	1.06	0.86	N/A
511									
512		-STAND-ALONE RO PLANT:							
513		TOTAL INVESTMENT ,M$	302.04	N/A	306.69	324.67	321.74	N/A	293.49
514		WATER CT, FIXED CHARGE, $/CU.M	0.33	N/A	0.33	0.32	0.32	N/A	0.33
515		WATER CT, ENERGY CHARGE, $/CU.M	0.33	N/A	0.27	0.25	0.25	N/A	0.22
516		WATER CT, O&M CHARGE, $/CU.M	0.26	N/A	0.26	0.26	0.26	N/A	0.26
517		TOTAL WATER COST, $/CU.M	0.92	N/A	0.85	0.82	0.82	N/A	0.81
518									
519		-CONTIGUOUS RO PLANT:							
520		TOTAL INVESTMENT ,M$	280.12	82.80	284.56	301.40	298.60	101.69	271.95
521		WATER CT, FIXED CHARGE, $/CU.M	0.30	0.33	0.30	0.30	0.30	0.32	0.30
522		WATER CT, ENERGY CHARGE, $/CU.M	0.32	0.31	0.26	0.24	0.24	0.21	0.22
523		WATER CT, O&M CHARGE, $/CU.M	0.26	0.26	0.26	0.26	0.26	0.26	0.26
524		TOTAL WATER COST, $/CU.M	0.89	0.90	0.82	0.80	0.80	0.79	0.78

ANNEX III

COUPLING BETWEEN SELECTED ENERGY SOURCES AND DESALINATION PROCESSES

FOR ORAN, ALGERIA (120,000 m^3/d)

(MATRIX AND SPREADSHEETS)

TABLE III.1: Oran, Algeria - 120,000 m^3/d

Primary Energy	Energy Cycle	Scheme	MED	Stand Alone RO	Contiguous RO	Hybrid
Nuclear	Steam Power Plant	CANDU 3 NP-300 CAREM-25	I Algeria-3 Algeria-1	II-A Algeria-3 Algeria-1 Algeria-5	II-B Algeria-3 Algeria-1 Algeria-5	III Algeria-2
	Power Brayton Cycle	GT-MHR			IV-B Algeria-4	
	Heat Only Steam Cycle	HR-200	V-a Algeria-9			
Fossil	Gas Turbine	oil/gas	IX Algeria-6	X-A Algeria-6	X-B Algeria-6	
	Gas Turbine Combined Cycle	oil/gas	Algeria-7	XIII-A Algeria-7	XIII-B Algeria-7	
	Diesel	oil/gas		XVI-A Algeria-8		

* Data given in this table are only indicative

	A	B	C	D	E	F	G	H	I	J	K
1		IAEA DESALINATION COST ANALYSIS - REGIONAL STUDY						ALGERIA.XLS			
2		ALGERIA SITE WITH WHO STANDARD						29-Sep-94			
3		(All values in U.S. Jan.94 $)									
4											
5		SPREADSHEET ORGANIZATION:	START ROW #	END ROW #							
6											
7		PLANT CHARACTERISTICS	17	38							
8		PERFORMANCE INPUT DATA	40	101							
9		COST INPUT DATA	103	140							
10		ECONOMIC PARAMETER INPUT DATA	142	157							
11		PERFORMANCE CALCULATIONS	159	212							
12		COST CALCULATIONS	214	251							
13		ECONOMIC EVALUATIONS	253	395							
14		SUMMARY	396	524							
15	i	(i = input data)									
16		PLANT AND SITE CHARACTERISTICS									
17											
18	i	CASE	Algeria-1	Algeria-2	Algeria-3	Algeria-4	Algeria-6	Algeria-6	Algeria-7	Algeria-8	Algeria-9
19	i	ASSUMED LOCATION	ORAN	ORAN	ORAN	ORAN	ORAN	ORAN	ORAN	ORAN	ORAN
20	i	WATER DEMAND, CU.M/D	120000	120000	120000	120000	120000	120000	120000	120000	120000
21	i	PLANT TYPE	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	FOSSIL	FOSSIL	FOSSIL	NUCLEAR
22	i	PRODUCT	HEAT & POWER	HEAT & POWER	HEAT & POWER	POWER ONLY	POWER ONLY	HEAT & POWER	HEAT & POWER	POWER ONLY	HEAT ONLY
23	i	REFERENCE TO GENERIC CASES	I, II	III	I, II	IV B	II B	IX, X	XIII, .	XVI	V
24	i	FUEL TYPE	UO2	UO2	nat UO2	UCO	UO2	GAS	GAS	OIL/GAS	UO2
25	i	REACTOR OR FOSSIL PLANT TYPE	PWR(NP-300)	PWR(NP-300)	CANDU-3	GT-MHR	CAREM-25	GAS TURBINE	COMBINED CYCLE	DIESEL	HR-200
26	i	SIZE CATEGORY	MEDIUM	MEDIUM	MEDIUM	MEDIUM	SMALL	MEDIUM	MEDIUM	SMALL	MEDIUM
27	i	WATER PLANT TYPE	MED OR RO	MED/ RO HYBRID	MED OR RO	RO	RO	MED OR RO	MED OR RO	RO	MED
28	i	SELECTED UNIT NET OUTPUT, MWe (MWt)	300	300	450	287	25	125	350	30	200
29	i	TOTAL NET OUTPUT, MWe (MWt)	300	300	450	287	25	125	350	30	200
30	i	SERVICE YEAR	2005	2005	2005	2005	2005	2005	2005	2005	2005
31	i	CURRENCY REFERENCE YEAR	1994	1994	1994	1994	1994	1994	1994	1994	1994
32	i	SALEABLE POWER	YES	YES	YES	YES	YES	YES	YES	YES	NO
33	i	ASSUMED AVG COOLING WATER TEMP, C	21	21	21	21	21	21	21	21	21
34	i	MED DESIGN COOLING WATER TEMP, C	27	27	27	27	27	27	27	27	27
35	i	RO DESIGN COOLING WATER TEMP, C	18	18	18	18	18	18	18	18	18
36	i	CONTIGUOUS RO PREHEAT TEMPERATURE, C	18	32	18	32	32	18	18	N/A	N/A
37	i	SEAWATER TOTAL DISSOLVED SOLIDS, PPM	38500	38500	38500	38500	38500	38500	38500	38500	38500
38	i	PRODUCT DRINKING WATER STANDARD	WHO	WHO	WHO	WHO	WHO	WHO	WHO	WHO	WHO
39											
40		PERFORMANCE INPUT DATA									
41	i	BASE POWER PLANT PERFORMANCE DATA:									
42	i	NET THERMAL EFFICIENCY, %	31.6	31.6	29.7	47.8	25.0	33.0	50.0	46.0	N/A
43	i	BOILER EFFICIENCY, %	N/A	N/A	N/A	N/A	N/A	0.92	0.92	N/A	N/A
44	i	MAIN STEAM TEMPERATURE, C	293	293	260	N/A	N/A	N/A	427	N/A	N/A
45	i	MAIN STEAM PRESSURE, BAR	77.8	77.8	46.9	N/A	N/A	N/A	81.6	N/A	N/A

	A	B	C	D	E	F	G	H	I	J	K
46	I	CONDENSER RANGE, C	8	8	8	N/A	N/A	N/A	8	N/A	N/A
47	I	CONDENSER COOLING WTR PUMP HEAD, BAR	1.7	1 7	1 7	N/A	N/A	N/A	1 7	N/A	N/A
48	I	CONDENSER COOLING WTR PUMP EFFICIENCY	0 9	0 9	0 9	N/A	N/A	N/A	0 9	N/A	N/A
49	I	CONDENSING TEMPERATURE, C	37	37	37	N/A	N/A	N/A	37	N/A	N/A
50	I	PLANNED OUTAGE RATE	0 100	0 100	0 100	0 100	0 100	0 100	0 100	0 050	0 050
51	I	UNPLANNED OUTAGE RATE	0 110	0 110	0 110	0 110	0 110	0 110	0 110	0 050	0 050
52											
53		DUAL-PURPOSE PLT PERFORMANCE DATA									
54		CONDENSING TEMPERATURE, C	53	48	47 5	N/A	N/A	N/A	60 8	N/A	N/A
55		INTERMEDIATE LOOP FLASH STM TEMP, C	46 5	41 5	41	N/A	N/A	N/A	N/A	N/A	92
56		INTERMEDIATE LOOP COND RTRN TEMP C	44 5	39 5	39	N/A	N/A	N/A	N/A	N/A	90
57	I	INTERMEDIATE LOOP PRESSURE LOSS, BAR	1	1	1	N/A	N/A	N/A	N/A	N/A	1 5
58	I	INTEMEDIATE LOOP PUMP EFFICIENCY	0 9	0 9	0 9	N/A	N/A	N/A	N/A	N/A	0 9
59											
60		MED WATER PLT PERFORMANCE DATA									
61	I	DESALINATION TECHNOLOGY	LT-MED	LT-MED	LT-MED	N/A	N/A	LT-MED	LT-MED	N/A	LT-MED
62	I	PRODUCT WATER TDS, PPM	25	25	25	N/A	N/A	25	25	N/A	25
63	I	MAXIMUM BRINE TEMPERATURE, C	44 5	39 5	39	N/A	N/A	84	58 3	N/A	90
64		SEAWATER TEMPERATURE, C	27	27	27	N/A	N/A	27	27	N/A	27
65	I	MED CONDENSER RANGE, C	5	5	5	N/A	N/A	5	5	N/A	5
66	I	MED CONDENSER APPROACH, C	2	2	2	N/A	N/A	2	2	N/A	2
67		MINIMUM CONDENSING TEMPERATURE, C	34	34	34	N/A	N/A	34	34	N/A	34
68		OVERALL MED WORKING TEMPERATURE, C	11	6	5	N/A	N/A	50	24	N/A	56
69		TEMPERATURE DROP BETWEEN EFFECTS, C	1 90	1 79	1 78	N/A	N/A	2 59	2 16	N/A	2 68
70		NUMBER OF EFFECTS	6	4	3	N/A	N/A	20	12	N/A	21
71		GOR, kg PRODUCT/kg STEAM	5 5	3 8	2 9	N/A	N/A	14 5	9 9	N/A	15 0
72	I	UNIT SIZE, CU M/D	24,000	24,000	24,000	N/A	N/A	48,000	48,000	N/A	48 000
73		SEAWATER/PRODUCT FLOW RATIO	18 9	27 4	36 0	N/A	N/A	7 2	10 5	N/A	6 9
74	I	SEAWATER HEAD + PRESS LOSS, BAR	1.7	1 7	1 7	N/A	N/A	1 7	1 7	N/A	1 7
75	I	SEAWATER PUMP EFFICIENCY	0 9	0 9	0 9	N/A	N/A	0 9	0 9	N/A	0 9
76	I	WATER PLANT SPEC PWR USE kWe/CU M/D	0 083	0 083	0 083	N/A	N/A	0 083	0 083	N/A	0 083
77	I	WTR PLT PLANNED OUTAGE RATE	0 030	0 030	0 030	N/A	N/A	0 030	0 030	N/A	0 030
78	I	WTR PLT UNPLANNED OUTAGE RATE	0 065	0 065	0 065	N/A	N/A	0 065	0 065	N/A	0 065
79		BACKUP HEAT SOURCE SIZE, MWt	652 80	646 88	1062 35	N/A	N/A	214 91	352 97	N/A	200 00
80	I	BACKUP HEAT SOURCE AVAILABILITY	0 9	0 9	0 9	N/A	N/A	0 9	0 9	N/A	0 9
81											
82		MEMBRANE WATER PLT PERFORMANCE DATA									
83	I	NO STAGES TO MEET WATER STANDARD	1	1	1	1	1	1	1	1	
84		SEAWATER TDS, PPM	38,500	38 500	38,500	38 500	38,500	38,500	38 500	38,500	N/A
85	I	RO PRODUCT WATER TDS, PPM	270	270	270	270	270	270	270	270	N/A
86		WATER FLUX INCREASE FACTOR FROM TEMP	1	1 1	1	1 1	1 1	1	1	1	N/A
87		OUTPUT PER UNIT, CU M/D	24,000	26 400	24,000	26,400	26,400	24,000	24,000	24,000	N/A
88		RECOVERY RATIO	0 50	0 55	0 50	0 60	0 55	0.50	0 50	0 50	N/A
89	I	SEAWATER PUMP HEAD, BAR	1.7	1 7	1 7	1 7	1.7	1.7	1.7	1 7	N/A
90	I	SEAWATER PUMP EFFICIENCY	0 9	0 9	0 9	0 9	0 9	0.9	0 9	0 9	N/A
91	I	BOOSTER PUMP HEAD, BAR	3 3	3 3	3 3	3 3	3 3	3 3	3 3	3 3	N/A
92	I	BOOSTER PUMP EFFICIENCY	0 9	0 9	0 9	0 9	0 9	0 9	0 9	0 9	N/A
93	I	STAGE 1 HIGH HD PUMP PRESS RISE, BAR	82	82	82	82	82	82	82	82	N/A
94	I	STAGE 1 HIGH HEAD PUMP EFFICIENCY	0 85	0 85	0 85	0 85	0 85	0 85	0 85	0 85	N/A
95	I	STG 1 HYDRAULIC COUPLING EFFICIENCY	0 965	0 965	0 965	0 965	0 965	0 965	0 965	0 965	N/A

	A	B	C	D	E	F	G	H	I	J	K
96	i	ENERGY RECOVERY EFFICENCY	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	N/A
97	i	STG 2 HYDRAULIC COUPLING EFFICIENCY	0.965	0.965	0.965	0.965	0.965	0.965	0.965	0.965	N/A
98	i	STAGE 2 HIGH HD PUMP PRESS RISE, BAR	0	0	0	0	0	0	0	0	N/A
99	i	STAGE 2 HIGH HEAD PUMP EFFICIENCY	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	N/A
100	i	OTHER SPECIFIC POWER USE, kWe/CU.M/D	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	N/A
101	i	RO PLANT AVAILABILITY	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	N/A
102											
103		COST INPUT DATA									
104											
105		POWER PLANT COST DATA:									
106	i	SPEC. CONSTR. COST, $/kWe ($/kWt)	2200	2200	2140.41	2020	2000	500	650	1000	550
107		ADDITIONL CONSTR. COST, $/kWe ($/kWt)	220	220	214	202	200	50	65	100	55
108		TOTAL CONSTR. COST, $/kWe ($/kWt)	2420	2420	2354	2222	2200	550	715	1100	605
109	i	CONSTRUCTION LEAD TIME, MONTHS	60	60	60	48	48	48	36	18	40
110	i	SPECIFIC O&M COST, $/MWeh ($/MWth)	13.09	13.09	11.00	8.65	8.80	6.60	5.50	7.70	2.53
111	i	GAS PRICE AT STARTUP, $/BOE	N/A	N/A	N/A	N/A	N/A	15.50	15.50	15.50	N/A
112	i	SPECIFIC FUEL COST, $/MWeh ($/MWth)	13.89	13.89	4.35	9.20	16.80	28.52	18.82	20.46	2.59
113		LEVELIZED ANNUAL DECOMM. COST, M$	2.11	2.11	3.16	2.01	0.18	0.00	0.00	0.00	0.52
114	i	FUEL ANNUAL REAL ESCALATION, %	0	0	0	0	0	2	2	2	0
115											
116		THERMAL WATER PLANT COST DATA:									
117	i	CORRECTION FACTOR FOR UNIT SIZE	0.9	0.9	0.9	N/A	N/A	0.9	0.9	N/A	0.9
118	i	BASE UNIT COST, $/CU.M/D	1440	1440	1440	N/A	N/A	1440	1440	N/A	1440
119		INTERMEDIATE LOOP UNIT COST, $/CU.M/D	201	292	382	N/A	N/A	0	0	N/A	74
120	i	WATER PLT COST CONTG'CY FACTOR	0.10	0.10	0.10	N/A	N/A	0.10	0.10	N/A	0.10
121	i	WATER PLT OWNERS COST FACTOR	0.05	0.05	0.05	N/A	N/A	0.05	0.05	N/A	0.05
122	i	WATER PLT LEAD TIME,MONTHS	36	36	36	N/A	N/A	36	36	N/A	24
123	i	AVERAGE MANAGEMENT SALARY, $/YR	66000	66000	66000	N/A	N/A	66000	66000	N/A	66000
124	i	AVERAGE LABOR SALARY, $/YR	29700	29700	29700	N/A	N/A	29700	29700	N/A	29700
125	i	SPECIFIC O&M SPARE PARTS COST, $/CU.M	0.04	0.04	0.04	N/A	N/A	0.04	0.04	N/A	0.04
126	i	SPECIFIC O&M CHEM COST, $/CU.M	0.02	0.02	0.02	N/A	N/A	0.02	0.02	N/A	0.02
127	i	WATER PLT O&M INS COST,% BASE CAP	0.50	0.50	0.50	N/A	N/A	0.50	0.50	N/A	0.50
128	i	BACKUP HEAT SOURCE UNIT COST, $/MWt	55000	55000	55000	N/A	N/A	55000	55000	N/A	50000
129											
130		MEMBRANE WATER PLANT COST DATA:									
131	i	BASE UNIT COST, $/CU.M/D	1125	1023	1125	1023	1023	1125	1125	1125	N/A
132	i	WATER PLT COST CONTG'CY FACTOR	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	N/A
133	i	WATER PLT OWNERS COST FACTOR	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	N/A
134	i	WATER PLT LEAD TIME,MONTHS	24	24	24	24	24	24	24	24	N/A
135	i	AVERAGE MANAGEMENT SALARY, $/YR	66000	66000	66000	66000	66000	66000	66000	66000	N/A
136	i	AVERAGE LABOR SALARY, $/YR	29700	29700	29700	29700	29700	29700	29700	29700	N/A
137	i	O&M MEMBRANE REPLACEMENT COST, $/CU.M	0.12	0.11	0.12	0.11	0.11	0.12	0.12	0.12	N/A
138	i	O&M SPARE PARTS COST, $/CU.M	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	N/A
139	i	SPECIFIC CHEMICAL COST, $/CU.M	0.07	0.06	0.07	0.06	0.06	0.07	0.07	0.07	N/A
140	i	WATER PLT O&M INS COST,% BASE CAP	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	N/A
141											
142		ECONOMIC PARAMETERS INPUT DATA									
143											
144		CASE 1: 5% INTEREST RATE									
145	i	AFUDC RATE, %/YR	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

	A	B	C	D	E	F	G	H	I	J	K
146		LN-94$ FIXED CHARGE RATE, %	6.51	6.51	6.51	6.51	6.51	6.51	6.51	6.51	6.51
147	i	PURCHASED ELECTRICITY COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.04
148											
149		CASE 2: 8% INTEREST RATE									
150	i	AFUDC RATE, %/YR	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
151		LN-94$ FIXED CHARGE RATE, %	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88
152	i	PURCHASED ELECTRICITY COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.05
153											
154		CASE 3: 10% INTEREST RATE									
155	i	AFUDC RATE, %/YR	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
156		LN-94$ FIXED CHARGE RATE, %	10.61	10.61	10.61	10.61	10.61	10.61	10.61	10.61	10.61
157	i	PURCHASED ELECTRICITY COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.06
158											
159		PERFORMANCE CALCULATIONS									
160											
161		SINGLE-PURPOSE PLT PERFORMANCE:									
162		THERMAL POWER, MWt	949.4	949.4	1515.2	600.4	100.0	378.8	700.0	65.2	200.0
163		PLANT GROSS OUTPUT, MWe	315.8	315.8	473.7	302.1	26.3	131.6	368.4	31.6	N/A
164		PLANT AUX LOADS, MWe	15.8	15.8	23.7	15.1	1.3	6.6	18.4	1.6	2.0
165		CONDENSER COOLING WTR FLOW, kg/s	19391	19391	31807	N/A	N/A	N/A	9331	N/A	N/A
166		CONDENSER COOLING WTR PUMP POWER, MWe	3.87	3.87	6.34	N/A	N/A	N/A	1.86	N/A	N/A
167		REJECT HEAT LOAD, MWt	633.6	633.6	1041.5	N/A	N/A	N/A	331.6	N/A	N/A
168		TURBINE EXHAUST FLOW, kg/s	275.5	275.5	452.8	N/A	N/A	N/A	144.2	N/A	N/A
169		OPERATING AVAILABILITY	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.903	0.903
170											
171		DUAL-PURPOSE POWER PLANT PERFORMANCE:									
172		LOST SHAFTWORK, MWs	19.2	13.3	20.9	N/A	N/A	N/A	21.4	N/A	N/A
173		LOST ELECTRICITY PRODUCTION, MWe	19.1	13.2	20.7	N/A	N/A	0.0	21.2	N/A	N/A
174		NET ELECTRICITY PRODUCED, MWe	280.9	286.8	429.3	N/A	N/A	125.0	328.8	30.0	N/A
175		TOTAL HEAT TO WTR PLT, MWt	653	647	1062	N/A	N/A	215	353	N/A	200
176		BACKPRESSURE TURB. EXHAUST FLOW, kg/s	283.8	281.3	461.9	N/A	N/A	N/A	153.5	N/A	N/A
177		INTERMEDIATE LOOP FLOW RATE, kg/s	78086	77378	127075	N/A	N/A	N/A	N/A	N/A	23923
178		INTERMEDIATE LOOP PUMPING POWER, MWe	9.16	9.08	14.91	N/A	N/A	N/A	N/A	N/A	4.21
179		FLASH STEAM FLOW TO MED, kg/s	281	279	458	N/A	N/A	93	152	N/A	86
180											
181		THERMAL WATER PLANT PERFORMANCE:									
182		MAXIMUM WATER PLT CAPACITY, CU.M/DAY	132,882	90,872	113,897	N/A	N/A	115,832	129,871	N/A	111,428
183		NUMBER OF UNITS	6	4	5	N/A	N/A	3	3	N/A	3
184		SEAWATER FLOW, kg/s	29,123	28,859	47,394	N/A	N/A	9,587	15,747	N/A	8,922
185		INCREMENTAL SEAWATER PUMPING PWR, MWe	1.94	1.89	3.11	N/A	N/A	1.91	1.28	N/A	1.78
186		WATER PLANT INTERNAL POWER USE, MWe	11.03	7.54	9.45	N/A	N/A	9.61	10.78	N/A	9.25
187		WTR PLT+INT.LOOP+SEAWTR PUMP PWR, MWe	22.13	18.51	27.47	N/A	N/A	11.53	12.06	N/A	15.24
188		WTR PLT OPERATING AVAILABILITY	0.907	0.907	0.907	N/A	N/A	0.907	0.907	N/A	0.907
189		COMBINED HEAT SOURCE AVAILABILITY	0.98	0.98	0.98	N/A	N/A	0.98	0.98	N/A	0.99
190		COMBINED PWR/WTR PLT CAPACITY FACTOR	0.889	0.889	0.889	N/A	N/A	0.889	0.889	N/A	0.898
191		ANNUAL WATER PRODUCTION, CU.M/YR	43,113,454	29,483,327	36,953,751	N/A	N/A	37,581,560	42,136,502	N/A	36,527,084
192		AVRG DAILY WATER PRODUCTION, CU.M/D	118,119	80,776	101,243	N/A	N/A	102,963	115,442	N/A	100,074
193											
194		RO WATER PLANT PERFORMANCE:									
195		PRODUCTION CAPACITY, CU.M/DAY	132882	29128	113897	120000	120000	115832	129871	120000	N/A

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	A	B	C	D	E	F	G	H	I	J	K
196		NUMBER OF RO UNITS	6	2	5	5	5	5	6	6	N/A
197		SEAWATER FLOW, kg/s	3076	613	2637	2315	2525	2681	3006	2778	N/A
198		STAND-ALONE SEAWATER PUMPING PWR, MWe	0.61	N/A	0.53	N/A	N/A	0.53	0.60	0.55	N/A
199		CONTIGUOUS SEAWATER PUMPING PWR, MWe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A
200		BOOSTER PUMP POWER, MWe	1.19	0.24	1.02	0.90	0.98	1.04	1.16	1.08	N/A
201		STAGE 1 HIGH HEAD PUMP POWER, MWe	32.47	6.47	27.83	24.43	26.65	28.30	31.73	29.32	N/A
202		ENERGY RECOVERY, MWe	11.50	2.06	9.86	6.93	8.50	10.03	11.24	10.39	N/A
203		STAGE 2 HIGH HEAD PUMP POWER, MWe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A
204		OTHER POWER, MWe	5.42	1.08	4.65	4.45	4.45	4.73	5.30	4.90	N/A
205		TOTAL STAND-ALONE POWER USE, MWe	28.19	N/A	24.16	N/A	N/A	24.57	27.55	25.46	N/A
206		TOTAL CONTIGUOUS POWER USE, MWe	27.57	5.72	23.63	22.85	23.58	24.04	26.95	N/A	N/A
207		ANNUAL AVG. WATER PRODUCTION, CU.M/YR	44,136,762	9,674,879	37,830,858	39,858,000	39,858,000	38,473,567	43,136,623	39,858,000	N/A
208		AVG. DAILY WATER PRODUCTION, CU.M/DAY	120,923	26,507	103,646	109,200	109,200	105,407	118,183	109,200	N/A
209		SPEC. (S-A) PWR CONSUMPTION, kWh/CU.M	5.09	N/A	5.09	N/A	N/A	5.09	5.09	5.09	N/A
210		SPEC.(CONT) PWR CONSUMPTION, kWh/CU.M	4.98	4.72	4.98	4.57	4.72	4.98	4.98	N/A	N/A
211		NET PWR PLNT SALEABLE PWR (S-A), MWe	271.81	N/A	425.84	N/A	N/A	100.43	322.45	4.54	N/A
212		NET PWR PLNT SALEABLE PWR (CONT), MWe	272.43	N/A	426.37	264.15	1.42	100.96	323.05	N/A	N/A
213											
214		COST CALCULATIONS									
215											
216		THERMAL WATER PLANT COSTS:									
217		NUMBER OF UNITS	6	4	5	N/A	N/A	3	3	N/A	3
218		CORRECTION FACTOR FOR NO. OF UNITS	0.888	0.935	0.911	N/A	N/A	0.959	0.959	N/A	0.959
219		WATER PLT SPECIFIC BASE COST,$/CU.M/D	1151	1211	1181	N/A	N/A	1243	1243	N/A	1243
220		INC. IN/OUTFALL SPEC. BS CT, $/CU.M/D	86	123	132	N/A	N/A	234	76	N/A	233
221		INTERMEDIATE LOOP COST, $/CU.M/D	201	292	382	N/A	N/A	0	0	N/A	74
222		TOTAL SPECIFIC BASE COST, $/CU.M/D	1439	1626	1695	N/A	N/A	1477	1318	N/A	1549
223		NUMBER OF MANAGEMENT PERSONNEL	7	6	7	N/A	N/A	7	7	N/A	7
224		WATER PLT O&M MGMT COST,M$/Y	0.46	0.40	0.46	N/A	N/A	0.46	0.46	N/A	0.46
225		NUMBER OF LABOR PERSONNEL	36	31	34	N/A	N/A	35	36	N/A	34
226		WATER PLT O&M LABOR COST,M$/Y	1.08	0.93	1.02	N/A	N/A	1.03	1.07	N/A	1.01
227		WATER PLT ADJUSTED BASE COST,M$	191.18	147.74	193.10	N/A	N/A	171.07	171.22	N/A	172.65
228		BACKUP HEAT SOURCE BASE COST, M$	35.90	35.58	58.43	N/A	N/A	11.82	19.41	N/A	10.00
229		TOTAL WATER PLANT BASE COST, M$	227.08	183.32	251.53	N/A	N/A	182.89	190.64	N/A	182.65
230		WATER PLT OWNERS COST,M$	11.35	9.17	12.58	N/A	N/A	9.14	9.53	N/A	9.13
231		WATER PLT CONTINGENCY ,M$	23.84	19.25	26.41	N/A	N/A	19.20	20.02	N/A	19.18
232		WATER PLT TOT CONSTRUCTION COST ,M$	262.28	211.73	290.51	N/A	N/A	211.24	220.18	N/A	210.96
233		WATER PLT O&M COST,M$/YR	5.09	3.83	4.66	N/A	N/A	4.60	4.92	N/A	4.53
234											
235		RO WATER PLANT COSTS:									
236		NUMBER OF UNITS	6	2	5	5	5	5	6	6	N/A
237		CORRECTION FACTOR FOR NO. OF UNITS	0.888	0.983	0.911	0.911	0.911	0.911	0.888	0.888	N/A
238		PROCESS PLT SPECIFIC COST,$/CU.M/D	999	1006	1025	932	932	1025	999	999	N/A
239		STND-ALN IN/OUTFALL SPEC.CT, $/CU.M/D	103	N/A	110	N/A	N/A	109	104	108	N/A
240		STND-ALN WTR PLNT SPEC. CT, $/CU.M/D	1103	N/A	1135	N/A	N/A	1134	1104	1107	N/A
241		NUMBER OF MANAGEMENT PERSONNEL	7	5	7	6	6	7	7	7	N/A
242		O&M MGMT COST,M$/Y	0.46	0.33	0.46	0.40	0.40	0.46	0.46	0.46	N/A
243		NUMBER OF LABOR PERSONNEL	36	18	34	32	32	35	36	35	N/A
244		O&M LABOR COST,M$/Y	1.08	0.54	1.02	0.95	0.95	1.03	1.07	1.04	N/A
245		STND-ALN WTR PLT ADJUSTED BASE CT,M$	146.53	N/A	129.27	N/A	N/A	131.38	143.33	132.84	N/A

	A	B	C	D	E	F	G	H	I	J	K
246		CONTIGUOUS WTR PLT ADJUSTED BS CT,M$	132.80	29.30	116.76	111.83	111.83	118.74	129.79	N/A	N/A
247		WATER PLT OWNERS COST,M$	7.33	1.46	6.46	5.59	5.59	6.57	7.17	6.64	N/A
248		WATER PLT CONTINGENCY ,M$	15.39	3.08	13.57	11.74	11.74	13.80	15.05	13.95	N/A
249		STND-ALN WTR PLT TOT CONSTRUCT CT, M$	169.24	N/A	149.31	N/A	N/A	151.75	165.55	153.43	N/A
250		CONTIGUOUS WTR PLT TOT CONSTR CT, M$	155.52	33.84	136.80	129.17	129.17	139.11	152.01	N/A	N/A
251		WATER PLT O&M COST,M$/YR	11.99	2.95	10.45	9.87	9.87	10.61	11.74	10.94	N/A
252											
253		ECONOMIC EVALUATIONS									
254											
255		CASE 1: 5% INTEREST RATE									
256		-POWER PLANT COST									
257		TOTAL CONSTRUCTION COST, M$	726.00	726.00	1059.51	637.71	55.00	68.75	250.25	33.00	121.00
258		AFUDC, M$	94.18	94.18	137.45	65.37	5.64	7.05	19.00	1.23	10.25
259		TOTAL PLANT INVESTMENT, M$	820.18	820.18	1196.95	703.08	60.64	75.80	269.25	34.23	131.25
260		LEVELIZED ANNUAL CAPITAL COST, M$	53.35	53.35	77.86	45.74	3.94	4.93	17.52	2.23	8.54
261		*FUEL LEVELIZED FACTOR*	1.00	1.00	1.00	1.00	1.00	1.60	1.60	1.60	1.00
262		ANNUAL FUEL COST, M$	29.24	29.24	13.74	18.53	2.95	39.95	73.84	7.75	4.10
263		ANNUAL O&M COST, M$	27.55	27.55	34.73	17.41	1.54	5.79	13.51	1.83	4.00
264		ELEC. PWR COST (HEAT ONLY), M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.63
265		DECOMMISSIONING COST, M$	2.11	2.11	3.16	2.01	0.18	0.00	0.00	0.00	0.52
266		TOTAL ANNUAL REQUIRED REVENUE, M$	112.25	112.25	129.49	83.69	8.61	50.67	104.86	11.80	17.79
267		ANNUAL ELECTRICITY PRODUCTION, kWh	2,105,028,000	2,105,028,000	3,157,542,000	2,013,810,120	175,419,000	877,095,000	2,455,866,000	237,177,000	N/A
268		LEVELIZED POWER COST, $/kWh	0.053	0.053	0.041	0.042	0.049	0.058	0.043	0.050	N/A
269											
270		-THERMAL (MED) PLANT:									
271		ANNUAL WATER PROD, CU.M/YR	43,113,454	29,483,327	36,953,751	N/A	N/A	37,581,560	42,136,502	N/A	36,527,084
272		TOTAL CONSTRUCTION COST, M$	262.28	211.73	290.51	N/A	N/A	211.24	220.18	N/A	210.96
273		AFUDC ,M$	19.92	16.08	22.06	N/A	N/A	16.04	16.72	N/A	10.55
274		TOTAL INVESTMENT ,M$	282.20	227.81	312.57	N/A	N/A	227.28	236.90	N/A	221.50
275		WATER CT, *FIXED CHARGE*, M$/YR	18.36	14.82	20.33	N/A	N/A	14.78	15.41	N/A	14.41
276		WATER CT, HEAT CHARGE, M$/YR	7.91	5.47	6.61	N/A	N/A	0.00	7.05	N/A	17.79
277		WATER CT, ELEC CHARGE, M$/YR	9.19	7.69	8.77	N/A	N/A	5.19	4.01	N/A	4.80
278		WATER CT, O&M CHARGE, M$/YR	5.09	3.83	4.66	N/A	N/A	4.60	4.92	N/A	4.53
279		TOTAL WATER COST, $/CU.M	0.94	1.08	1.09	N/A	N/A	0.65	0.74	N/A	1.14
280											
281		-STAND-ALONE RO PLANT:									
282		SPECIFIED OUTPUT									
283		ANNUAL WATER PROD, CU.M/YR	44,136,762	N/A	37,830,858	N/A	N/A	38,473,567	43,136,623	39,858,000	N/A
284		TOTAL CONSTRUCTION COST ,M$	169.24	N/A	149.31	N/A	N/A	151.75	165.55	153.43	N/A
285		AFUDC ,M$	8.46	N/A	7.47	N/A	N/A	7.59	8.28	7.67	N/A
286		TOTAL INVESTMENT ,M$	177.70	N/A	156.77	N/A	N/A	159.33	173.82	161.10	N/A
287		WATER CT, FIXED CHARGE, M$/YR	11.56	N/A	10.20	N/A	N/A	10.36	11.31	10.48	N/A
288		WATER CT, ELEC CHARGE, M$/YR	11.98	N/A	7.90	N/A	N/A	11.32	9.38	10.10	N/A
289		WATER CT, O&M CHARGE, M$/YR	11.99	N/A	10.45	N/A	N/A	10.61	11.74	10.94	N/A
290		TOTAL WATER COST, $/CU.M	0.81	N/A	0.75	N/A	N/A	0.84	0.75	0.79	N/A
291		-CONTIGUOUS RO PLANT:									
292		ANNUAL WATER PROD, CU.M/YR	44,136,762	9,674,879	37,830,858	39,858,000	39,858,000	38,473,567	43,136,623	N/A	N/A
293		TOTAL CONSTRUCTION COST ,M$	155.52	33.84	136.80	129.17	129.17	139.11	152.01	N/A	N/A
294		AFUDC ,M$	7.78	1.69	6.84	6.46	6.46	6.96	7.60	N/A	N/A
295		TOTAL INVESTMENT ,M$	163.29	35.53	143.64	135.63	135.63	146.08	159.61	N/A	N/A

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	A	B	C	D	E	F	G	H	I	J	K
296		WATER CT, FIXED CHARGE, M$/YR	10.62	2.31	9.34	8.82	8.82	9.50	10.38	N/A	N/A
297		WATER CT, ELEC CHARGE, M$/YR	11.72	2.43	7.73	7.57	9.23	11.07	9.17	N/A	N/A
298		WATER CT, O&M CHARGE, M$/YR	11.99	2.95	10.45	9.87	9.87	10.61	11.74	N/A	N/A
299		TOTAL WATER COST, $/CU.M	0.78	0.80	0.73	0.66	0.70	0.81	0.73	N/A	N/A
300											
301		HYBRID MED/RO									
302		HYBRID ANNUAL WATER PRODUCTION	N/A	39,158,206	N/A	N/A	N/A	N/A	N/A	N/A	N/A
303		COMBINED WTR COST FOR HYBRID, $/CU.M	N/A	1.01	N/A	N/A	N/A	N/A	N/A	N/A	N/A
304											
305		*CASE 2: 8% INTEREST RATE*									
306		-POWER PLANT COST									
307		TOTAL CONSTRUCTION COST, M$	726.00	726.00	1059 51	637.71	55.00	68.75	250.25	33.00	121.00
308		AFUDC, M$	154.03	154.03	224.78	106.12	9.15	11.44	30.62	1.96	16.56
309		TOTAL PLANT INVESTMENT, M$	880.03	880.03	1284.29	743.83	64.15	80.19	280.87	34.96	137.56
310		LEVELIZED ANNUAL CAPITAL COST, M$	78.17	78.17	114.08	66.07	5.70	7.12	24.95	3.11	12.22
311		FUEL LEVELIZED FACTOR	1.00	1.00	1.00	1.00	1.00	1.54	1.54	1.54	1.00
312		ANNUAL FUEL COST, M$	29.24	29.24	13.74	18.53	2.95	38.51	71.16	7.47	4.10
313		ANNUAL O&M COST, M$	27.55	27.55	34.73	17.41	1.54	5.79	13.51	1.83	4.00
314		DECOMMISSIONING COST, M$	2.11	2.11	3.16	2.01	0.18	0.00	0.00	0.00	0.52
315		ELEC. PWR COST (HEAT ONLY), M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.79
316		TOTAL ANNUAL REQUIRED REVENUE, M$	137.07	137.07	165.71	104.02	10.36	51.42	109.62	12.40	21.63
317		ANNUAL ELECTRICITY PRODUCTION, KWH	2,105,028,000	2,105,028,000	3,157,542,000	2,013,810,120	175,419,000	877,095,000	2,455,866,000	237,177,000	N/A
318		LEVELIZED POWER COST, $/kWh	0.065	0.065	0.052	0.052	0.059	0.059	0.045	0.052	N/A
319											
320		-THERMAL (MED) PLANT:									
321		TOTAL CONSTRUCTION COST, M$	262.28	211.73	290.51	N/A	N/A	211.24	220.18	N/A	210.96
322		AFUDC, M$	32.10	25.91	35.55	N/A	N/A	25.85	26.94	N/A	16.88
323		TOTAL WATER PLANT INVESTMENT, M$	294.38	237.64	326.06	N/A	N/A	237.09	247.13	N/A	227.83
324		WATER CT, FIXED CHARGE, M$/YR	26.15	21.11	28.96	N/A	N/A	21.06	21.95	N/A	20.24
325		WATER CT, HEAT CHARGE, M$/YR	9.66	6.68	8.46	N/A	N/A	0.00	7.37	N/A	21.63
326		WATER CT, ELEC CHARGE, M$/YR	11.22	9.38	11.23	N/A	N/A	5.28	4.19	N/A	5.99
327		WATER CT, O&M CHARGE, M$/YR	5.09	3.83	4.66	N/A	N/A	4.60	4.92	N/A	4.53
328		TOTAL WATER COST, $/CU.M	1.21	1.39	1.44	N/A	N/A	0.82	0.91	N/A	1.43
329											
330		-STAND-ALONE RO PLANT:									
331		TOTAL CONSTRUCTION COST ,M$	169.24	N/A	149.31	N/A	N/A	151.75	165.55	153.43	N/A
332		AFUDC ,M$	13.54	N/A	11.94	N/A	N/A	12.14	13.24	12.27	N/A
333		TOTAL INVESTMENT ,M$	182.78	N/A	161.25	N/A	N/A	163.88	178.79	165.70	N/A
334		WATER CT, FIXED CHARGE, M$/YR	16.24	N/A	14.32	N/A	N/A	14.56	15.88	14.72	N/A
335		WATER CT, ELEC CHARGE, M$/YR	14.63	N/A	10.11	N/A	N/A	11.48	9.80	10.61	N/A
336		WATER CT, O&M CHARGE, M$/YR	11.99	N/A	10.45	N/A	N/A	10.61	11.74	10.94	N/A
337		TOTAL WATER COST, $/CU.M	0.97	N/A	0.92	N/A	N/A	0.95	0.87	0.91	N/A
338		-CONTIGUOUS RO PLANT:									
339		TOTAL CONSTRUCTION COST ,M$	155.52	33.84	136.80	129.17	129.17	139.11	152.01	N/A	N/A
340		AFUDC ,M$	12.44	2.71	10.94	10.33	10.33	11.13	12.16	N/A	N/A
341		TOTAL INVESTMENT ,M$	167.96	36.55	147.74	139.50	139.50	150.24	164.17	N/A	N/A
342		WATER CT, FIXED CHARGE, M$/YR	14.92	3.25	13.12	12.39	12.39	13.35	14.58	N/A	N/A
343		WATER CT, ELEC CHARGE, M$/YR	14.31	2.97	9.89	9.41	11.11	11.23	9.59	N/A	N/A
344		WATER CT, O&M CHARGE, M$/YR	11.99	2.95	10.45	9.87	9.87	10.61	11.74	N/A	N/A
345		TOTAL WATER COST, $/CU.M	0.93	0.95	0.88	0.79	0.84	0.91	0.83	N/A	N/A

	A	B	C	D	E	F	G	H	I	J	K
346											
347		HYBRID MED/RO									
348		HYBRID ANNUAL WATER PRODUCTION	N/A	39,158,206	N/A	N/A	N/A	N/A	N/A	N/A	N/A
349		COMBINED WTR COST FOR HYBRID, $/CU M	N/A	1 28	N/A	N/A	N/A	N/A	N/A	N/A	N/A
350											
351		CASE 3 10% INTEREST RATE									
352		-POWER PLANT COST									
353		TOTAL CONSTRUCTION COST M$	726 00	726 00	1059 51	637 71	55 00	68 75	250 25	33 00	121 00
354		AFUDC, M$	195 34	195 34	285 07	133 92	11 55	14 44	38 46	2 45	20 83
355		TOTAL PLANT INVESTMENT, M$	921 34	921 34	1344 57	771 63	66 55	83 19	288 71	35 45	141 83
356		LEVELIZED ANNUAL CAPITAL COST M$	97 73	97 73	142 63	81 85	7 06	8 82	30 63	3 76	15 05
357		FUEL LEVELIZED FACTOR	1 00	1 00	1 00	1 00	1 00	1 51	1 51	1 51	1 00
358		ANNUAL FUEL COST, M$	29 24	29 24	13 74	18 53	2 95	37 69	69 66	7 31	4 10
359		ANNUAL O&M COST, M$	27 55	27 55	34 73	17 41	1 54	5 79	13 51	1 83	4 00
360		DECOMMISSIONING COST M$	2,11	2 11	3 16	2 01	0 18	0 00	0 00	0 00	0 52
361		ELEC PWR COST (HEAT ONLY), M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0 95
362		TOTAL ANNUAL REQUIRED REVENUE M$	156 63	156 63	194 26	119 81	11 73	52 31	113 79	12 90	24 61
363		ANNUAL ELECTRICITY PRODUCTION KWH	2 105,028,000	2,105 028,000	3 157,542,000	2 013 810,120	175 419,000	877,095,000	2,455,866,000	237,177,000	N/A
364		LEVELIZED POWER COST $/kWh	0 074	0 074	0 062	0 059	0 067	0 060	0 046	0 054	N/A
365											
366		-THERMAL (MED) PLANT:									
367		TOTAL CONSTRUCTION COST	262 28	211 73	290 51	N/A	N/A	211 24	220 18	N/A	210 96
368		AFUDC ,M$	40 31	32 54	44 65	N/A	N/A	32 47	33 84	N/A	21 10
369		TOTAL INVESTMENT ,M$	302 59	244 27	335 16	N/A	N/A	243 70	254 02	N/A	232 05
370		WATER CT, FIXED CHARGE M$/YR	32 10	25 91	35 55	N/A	N/A	25 85	26 95	N/A	24 62
371		WATER CT, HEAT CHARGE, M$/YR	11 04	7 64	9 91	N/A	N/A	0 00	7 65	N/A	24 61
372		WATER CT, ELEC CHARGE M$/YR	12 82	10 72	13 16	N/A	N/A	5 35	4 35	N/A	7 19
373		WATER CT, O&M CHARGE, M$/YR	5 09	3 83	4 66	N/A	N/A	4 60	4 92	N/A	4 53
374		TOTAL WATER COST, $/CU M	1 42	1 63	1 71	N/A	N/A	0 95	1 04	N/A	1 67
375											
376		-STAND-ALONE RO PLANT.									
377		TOTAL CONSTRUCTION COST, M$	169 24	N/A	149 31	N/A	N/A	151.75	165 55	153 43	N/A
378		AFUDC, M$	16 92	N/A	14 93	N/A	N/A	15 17	16 55	15 34	N/A
379		TOTAL INVESTMENT ,M$	186 16	N/A	164 24	N/A	N/A	166 92	182 10	168 77	N/A
380		WATER CT, FIXED CHARGE, M$/YR	19 75	N/A	17 42	N/A	N/A	17.71	19 32	17.90	N/A
381		WATER CT, ELEC CHARGE, M$/YR	16 72	N/A	11 85	N/A	N/A	11 68	10 18	11 04	N/A
382		WATER CT, O&M CHARGE, M$/YR	11 99	N/A	10 45	N/A	N/A	10 61	11 74	10 94	N/A
383		TOTAL WATER COST, $/CU M	1 10	N/A	1 05	N/A	N/A	1.04	0 96	1 00	N/A
384		-CONTIGUOUS RO PLANT:									
385		TOTAL CONSTRUCTION COST, M$	155 52	33 84	136 80	129 17	129 17	139 11	152 01	N/A	N/A
386		AFUDC, M$	15 55	3 38	13 68	12 92	12 92	13 91	15 20	N/A	N/A
387		TOTAL INVESTMENT ,M$	171 07	37 22	150 48	142 08	142 08	153 02	167 21	N/A	N/A
388		WATER CT, FIXED CHARGE, M$/YR	18 15	3 95	15 96	15 07	15 07	16.23	17 74	N/A	N/A
389		WATER CT, ELEC CHARGE, M$/YR	16 36	3 40	11 59	10 84	12 57	11.43	9 95	N/A	N/A
390		WATER CT, O&M CHARGE, M$/YR	11 99	2 95	10 45	9 87	9 87	10 61	11 74	N/A	N/A
391		TOTAL WATER COST, $/CU M	1 05	1 06	1 00	0 90	0 94	0 99	0 91	N/A	N/A
392											
393		HYBRID MED/RO									
394		HYBRID ANNUAL WATER PRODUCTION	N/A	39 158 206	N/A	N/A	N/A	N/A	N/A	N/A	N/A
395		COMBINED WTR COST FOR HYBRID $/CU M	N/A	1 49	N/A	N/A	N/A	N/A	N/A	N/A	N/A

ALGERIA.XLS

	A	B	C	D	E	F	G	H	I	J	K
396											
397		SUMMARY									
398											
399		CASE	Algeria-1	Algeria-2	Algeria-3	Algeria-4	Algeria-5	Algeria-6	Algeria-7	Algeria-8	Algeria-9
400		PLANT TYPE	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	FOSSIL	FOSSIL	FOSSIL	NUCLEAR
401		PRODUCT	HEAT & POWER	HEAT & POWER	HEAT & POWER	POWER ONLY	POWER ONLY	HEAT & POWER	HEAT & POWER	POWER ONLY	HEAT ONLY
402		REFERENCE OF FLOW DIAGRAM	I, II	III	I, II	IV B	II B	X, XI	XIII, XIV	XVI	V
403		WATER PLANT TYPE	MED OR RO	MED/ RO HYBRID	MED OR RO	RO	RO	MED OR RO	MED OR RO	RO	MED
404		REACTOR TYPE	PWR(NP-300)	PWR(NP-300)	CANDU-3	GT-MHR	CAREM-25	GAS TURBINE	COMBINED CYCLE	DIESEL	HR-200
405		SELECTED NET OUTPUT, MWe (MWt)	300	300	450	287	25	125	350	30	200
406		PRODUCT DRINKING WATER STANDARD	WHO	WHO	WHO	WHO	WHO	WHO	WHO	WHO	WHO
407											
408		SUMMARY CASE 1: 5% INT & AFUDC RATE									
409		-LEVELIZED POWER COST, $/kWh	0.053	0.053	0.041	0.042	0.049	0.058	0.043	0.050	N/A
410		-PURCHASED POWER COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.04
411		-THERMAL MED PLANT (OPTIMIZED)									
412		WATER PRODUCTION CAPACITY, CU.M/D	132882	90872	113897	N/A	N/A	115832	129871	N/A	111428
413		NET SALEABLE POWER, MWe	258.82	N/A	401.84	N/A	N/A	113.47	316.74	N/A	0.00
414		WATER COST, $/CU.M	0.94	1.08	1.09	N/A	N/A	0.65	0.74	N/A	1.14
415		-STAND-ALONE RO PLT (MED EQ. OUTPUT)									
416		WATER PRODUCTION CAPACITY, CU.M/D	132882	N/A	113897	N/A	N/A	115832	129871	120000	N/A
417		NET SALEABLE POWER, MWe	271.81	N/A	425.84	N/A	N/A	100.43	322.45	4.54	N/A
418		WATER COST, $/CU.M	0.81	N/A	0.75	N/A	N/A	0.84	0.75	0.79	N/A
419		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)									
420		WATER PRODUCTION CAPACITY, CU.M/D	132882	29128	113897	120000	120000	115832	129871	N/A	N/A
421		NET SALEABLE POWER, MWe	272.43	N/A	426.37	264.15	1.42	100.96	323.05	N/A	N/A
422		WATER COST, $/CU.M	0.78	0.80	0.73	0.66	0.70	0.81	0.73	N/A	N/A
423		-HYBRID COMBINED MED/RO									
424		WATER PRODUCTION CAPACITY, CU.M/D	N/A	120000	N/A	N/A	N/A	N/A	N/A	N/A	N/A
425		NET SALEABLE POWER, MWe	N/A	263	N/A	N/A	N/A	N/A	N/A	N/A	N/A
426		WATER COST, $/CU.M	N/A	1.01	N/A	N/A	N/A	N/A	N/A	N/A	N/A
427											
428		SUMMARY CASE 2: 8% INT & AFUDC RATE									
429		-LEVELIZED POWER COST, $/kWh	0.065	0.065	0.052	0.052	0.059	0.059	0.045	0.052	N/A
430		-PURCHASED POWER COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.05
431		-THERMAL MED PLANT (OPTIMIZED)									
432		WATER PRODUCTION CAPACITY, CU.M/D	132882	90872	113897	N/A	N/A	115832	129871	N/A	111428
433		NET SALEABLE POWER, MWe	258.82	N/A	401.84	N/A	N/A	113.47	316.74	N/A	0.00
434		WATER COST, $/CU.M	1.21	1.39	1.44	N/A	N/A	0.82	0.91	N/A	1.43
435		-STAND-ALONE RO PLT (MED EQ. OUTPUT)									
436		WATER PRODUCTION CAPACITY, CU M/D	132882	N/A	113897	N/A	N/A	115832	129871	120000	N/A
437		NET SALEABLE POWER, MWe	271.81	N/A	425.84	N/A	N/A	100.43	322.45	4.54	N/A
438		WATER COST, $/CU.M	0.97	N/A	0.92	N/A	N/A	0.95	0.87	0.91	N/A
439		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)									
440		WATER PRODUCTION CAPACITY, CU.M/D	132882	29128	113897	120000	120000	115832	129871	N/A	N/A
441		NET SALEABLE POWER, MWe	272.43	N/A	426.37	264.15	1.42	100.96	323.05	N/A	N/A
442		WATER COST, $/CU.M	0.93	0.95	0.88	0.79	0.84	0.91	0.83	N/A	N/A
443		-HYBRID COMBINED MED/RO									
444		WATER PRODUCTION CAPACITY, CU.M/D	N/A	120000	N/A	N/A	N/A	N/A	N/A	N/A	N/A
445		NET SALEABLE POWER, MWe	N/A	263	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	A	B	C	D	E	F	G	H	I	J	K
446		WATER COST, $/CU.M	N/A	1.28	N/A	N/A	N/A	N/A	N/A	N/A	N/A
447											
448		SUMMARY CASE 3: 10% INT & AFUDC RATE									
449		-LEVELIZED POWER COST, $/kWh	0 074	0 074	0 062	0 059	0.067	0.060	0.046	0.054	N/A
450		-PURCHASED POWER COST, $/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0 06
451		-THERMAL MED PLANT (OPTIMIZED)									
452		WATER PRODUCTION CAPACITY, CU M/D	132882	90872	113897	N/A	N/A	115832	129871	N/A	111428
453		NET SALEABLE POWER, MWe	258.82	N/A	401 84	N/A	N/A	113.47	316.74	N/A	0 00
454		WATER COST, $/CU.M	1.42	1.63	1 71	N/A	N/A	0.95	1.04	N/A	1.67
455		-STAND ALONE RO PLT (MED EQ. OUTPUT)									
456		WATER PRODUCTION CAPACITY, CU M/D	132882	N/A	113897	N/A	N/A	115832	129871	120000	N/A
457		NET SALEABLE POWER, MWe	271.81	N/A	425 84	N/A	N/A	100.43	322.45	4.54	N/A
458		WATER COST, $/CU.M	1.10	N/A	1 05	N/A	N/A	1.04	0.96	1.00	N/A
459		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)									
460		WATER PRODUCTION CAPACITY, CU M/D	132882	29128	113897	120000	120000	115832	129871	N/A	N/A
461		NET SALEABLE POWER, MWe	272.43	N/A	426 37	264 15	1.42	100.96	323.05	N/A	N/A
462		WATER COST, $/CU.M	1.05	1.06	1 00	0 90	0 94	0.99	0.91	N/A	N/A
463		-HYBRID COMBINED MED/RO									
464		WATER PRODUCTION CAPACITY, CU M/D	N/A	120000	N/A	N/A	N/A	N/A	N/A	N/A	N/A
465		NET SALEABLE POWER, MWe	N/A	263	N/A	N/A	N/A	N/A	N/A	N/A	N/A
466		WATER COST, $/CU.M	N/A	1.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A
467											
468		INVESTMENT COSTS - 8% INTEREST RATE									
469											
470		POWER PLANT									
471		SPECIFIC CONSTRUCTION COST, $/kW	2420	2420	2354	2222	2200	550	715	1100	605
472		- POWER PLANT CONSTRUCTION, M$	726	726	1060	638	55	69	250	33	121
473		- POWER PLANT IDC, M$	154	154	225	106	9	11	31	2	17
474		TOTAL INVESTMENT COST, M$	880	880	1284	744	64	80	281	35	138
475		SPECIFIC INVESTMENT COST, $/kW	2933	2933	2854	2592	2566	642	802	1165	688
476											
477		POWER & THERMAL MED PLANT									
478		- POWER PLANT CONSTRUCTION, M$	726	726	1060	N/A	N/A	69	250	33	121
479		- POWER PLANT IDC, M$	154	154	225	N/A	N/A	11	31	2	17
480		-PWR PLT COST PORTION OF WTR PROD M$	121	110	137	N/A	N/A	7	27	N/A	138
481		- MED PLANT CONSTRUCTION, M$	262	212	291	N/A	N/A	211	220	N/A	211
482		- MED PLANT IDC, M$	32	26	36	N/A	N/A	26	27	N/A	17
483		TOTAL INVESTMENT COST, M$	415	347	464	N/A	N/A	244	274	N/A	365
484		- MED CAPACITY, CU.M/D	132882	90872	113897	N/A	N/A	115832	129871	N/A	111428
485		SPECIFIC INVESTMENT COST, $/CU.M/D	3124	3823	4070	N/A	N/A	2111	2108	N/A	3279
486											
487		POWER & S-A RO (MED EQUIV.) PLANT									
488		- POWER PLANT CONSTRUCTION, M$	726	N/A	1060	N/A	N/A	69	250	33	N/A
489		- POWER PLANT IDC, M$	154	N/A	225	N/A	N/A	11	31	2	N/A
490		-PWR PLT COST PORTION OF WTR PROD M$	83	N/A	69	N/A	N/A	16	22	30	N/A
491		- RO PLANT CONSTRUCTION, M$	169	N/A	149	N/A	N/A	152	166	153	N/A
492		- RO PLANT IDC, M$	14	N/A	12	N/A	N/A	12	13	12	N/A
493		TOTAL INVESTMENT COST, M$	265	N/A	230	N/A	N/A	180	201	195	N/A
494		- RO (MED EQUIV.) CAPACITY, CU.M/D	132882	N/A	113897	N/A	N/A	115832	129871	120000	N/A
495		SPECIFIC INVESTMENT COST, $/CU M/D	1998	N/A	2021	N/A	N/A	1551	1547	1628	N/A

	A	B	C	D	E	F	G	H	I	J	K
496											
497		COST SUMMARY: 8% INTEREST RATE									
498											
499		-POWER PLANT COST									
500		TOTAL PLANT INVESTMENT, M$	880.03	880.03	1284 29	743 83	64.15	80.19	280.87	34.96	137 56
501		LEVELIZED ANNUAL CAPITAL COST, M$	78.17	78.17	114.08	66 07	5.70	7.12	24.95	3.11	12 22
502		TOTAL ANNUAL REQUIRED REVENUE, M$	137.07	137.07	165.71	104 02	10.36	51.42	109.62	12.40	21 63
503		LEVELIZED POWER COST, $/kWh	0.065	0 065	0 052	0 052	0 059	0 059	0.045	0.052	N/A
504											
505		-THERMAL (MED) PLANT:									
506		TOTAL WATER PLANT INVESTMENT, M$	294.38	237.64	326 06	N/A	N/A	237.09	247.13	N/A	227 83
507		WATER CT, FIXED CHARGE, $/CU.M	0.61	0.72	0 78	N/A	N/A	0.56	0.52	N/A	0 55
508		WATER CT, ENERGY CHARGE, $/CU.M	0.48	0.54	0 53	N/A	N/A	0.14	0.27	N/A	0 76
509		WATER CT, O&M CHARGE, $/CU.M	0.12	0.13	0 13	N/A	N/A	0.12	0.12	N/A	0 12
510		TOTAL WATER COST, $/CU M	1.21	1 39	1 44	N/A	N/A	0.82	0 91	N/A	1 43
511											
512		-STAND-ALONE RO PLANT:									
513		TOTAL INVESTMENT ,M$	182.78	N/A	161 25	N/A	N/A	163.88	178.79	165.70	N/A
514		WATER CT, FIXED CHARGE, $/CU M	0.37	N/A	0 38	N/A	N/A	0.38	0.37	0.37	N/A
515		WATER CT, ENERGY CHARGE, $/CU M	0.33	N/A	0.27	N/A	N/A	0.30	0.23	0.27	N/A
516		WATER CT, O&M CHARGE, $/CU M	0.27	N/A	0.28	N/A	N/A	0.28	0.27	0 27	N/A
517		TOTAL WATER COST, $/CU M	0.97	N/A	0 92	N/A	N/A	0.95	0.87	0 91	N/A
518											
519		-CONTIGUOUS RO PLANT:									
520		TOTAL INVESTMENT ,M$	167.96	36.55	147.74	139 50	139 50	150.24	164.17	N/A	N/A
521		WATER CT, FIXED CHARGE, $/CU M	0.34	0 34	0 35	0 31	0.31	0.35	0 34	N/A	N/A
522		WATER CT, ENERGY CHARGE, $/CU.M	0.32	0.31	0 26	0 24	0.28	0.29	0.22	N/A	N/A
523		WATER CT, O&M CHARGE, $/CU M	0.27	0.30	0.28	0 25	0.25	0.28	0.27	N/A	N/A
524		TOTAL WATER COST, $/CU M	0.93	0.95	0 88	0 79	0.84	0.91	0.83	N/A	N/A

ANNEX IV

COUPLING BETWEEN SELECTED ENERGY SOURCES AND DESALINATION PROCESSES

FOR ZARZIS, TUNISIA (60,000 m^3/d)

(MATRIX AND SPREADSHEETS)

TABLE IV.1: Zarzis, Tunisia - 60,000 m^3/d

Primary Energy	Energy Cycle	Scheme	MED	Stand Alone RO	Contiguous RO	Hybrid
Nuclear	Steam Power Plant	4S CAREM-25			II-B Tunisia-4 Tunisia-5	
	Heat Only Steam Cycle	THERMOS LT-4 TRIGA	V-a Tunisia-1 Tunisia-2 Tunisia-3			
Fossil	Gas Turbine Combined Cycle	oil/gas	XII-c Tunisia-6	XIII-A Tunisia-6	XIII-B Tunisia-6	
	Diesel	oil/gas		XVI Tunisia-7		XVII Tunisia-8
	Heat Only Boiler	oil/gas	XIX Tunisia-9			

* Data given in this table are only indicative

TUNISIA.XLS

IAEA DESALINATION COST ANALYSIS - REGIONAL STUDY

TUNISIA.XLS

TUNISIA SITE WITH WHO WATER QUALITY STANDARD

12-Oct-94

(All values in U.S. Jan.94 $)

Row	SPREADSHEET ORGANIZATION:	START ROW #	END ROW #
7	PLANT CHARACTERISTICS	17	38
8	PERFORMANCE INPUT DATA	40	101
9	COST INPUT DATA	103	140
10	ECONOMIC PARAMETER INPUT DATA	142	157
11	PERFORMANCE CALCULATIONS	159	212
12	COST CALCULATIONS	214	251
13	ECONOMIC EVALUATIONS	253	395
14	SUMMARY	396	524

15 i (i = input data)

16 PLANT AND SITE CHARACTERISTICS

Row	A	B	C	D	E	F	G	H	I	J	K
18	i	CASE	Tunisia-1	Tunisia-2	Tunisia-3	Tunisia-4	Tunisia-5	Tunisia-6	Tunisia-7	Tunisia-8	Tunisia-9
19	i	ASSUMED LOCATION	ZARZIS	ZARZIS	ZARZIS	ZARZIS	ZARZIS	ZARZIS	ZARZIS	ZARZIS	ZARZIS
20	i	WATER DEMAND, CU.M/D	60000	60000	60000	60000	60000	60000	60000	60000	60000
21	i	PLANT TYPE	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	FOSSIL	FOSSIL	FOSSIL	FOSSIL
22	i	PRODUCT	HEAT ONLY	HEAT ONLY	HEAT ONLY	POWER ONLY	POWER ONLY	HEAT & POWER	POWER ONLY	HEAT & POWER	HEAT ONLY
23	i	REFERENCE TO GENERIC CASES	V	V	V	II B	II B	XII XIII	XVI	XVII	XIX
24	i	FUEL TYPE	UO2	UO2	UZrH	U, Pu	UO2	GAS	OIL/GAS	OIL/GAS	GAS
25	i	REACTOR OR FOSSIL PLANT TYPE	THERMOS	LT-4	TRIGA	4S	CAREM-25	COMBINED CYCLE	DIESEL	DIESEL	FOSSIL BOILER
26	i	SIZE CATEGORY	MEDIUM	SMALL	SMALL	SMALL	SMALL	MEDIUM	SMALL	SMALL	MEDIUM
27	i	WATER PLANT TYPE	MED	MED	MED	RO	RO	MED OR RO	RO	MED/RO HYBRID	MED
28	i	SELECTED UNIT NET OUTPUT, MWe (MWt)	100	80	64	48	25	200	25	25	80
29	i	TOTAL NET OUTPUT, MWe (MWt)	100	80	64	48	25	200	25	25	80
30	i	SERVICE YEAR	2005	2005	2005	2005	2005	2005	2005	2005	2005
31	i	CURRENCY REFERENCE YEAR	1994	1994	1994	1994	1994	1994	1994	1994	1994
32	i	SALEABLE POWER	NO	NO	NO	YES	YES	YES	YES	YES	NO
33	i	ASSUMED AVG COOLING WATER TEMP, C	21	21	21	21	21	21	21	21	21
34	i	MED DESIGN COOLING WATER TEMP, C	27	27	27	27	27	27	27	27	27
35	i	RO DESIGN COOLING WATER TEMP, C	18	18	18	18	18	18	18	18	18
36	i	CONTIGUOUS RO PREHEAT TEMPERATURE, C	N/A	N/A	N/A	32	32	18	N/A	N/A	N/A
37	i	SEAWATER TOTAL DISSOLVED SOLIDS, PPM	38500	38500	38500	38500	38500	38500	38500	38500	38500
38	i	PRODUCT DRINKING WATER STANDARD	WHO	WHO	WHO	WHO	WHO	WHO	WHO	WHO	WHO
40		PERFORMANCE INPUT DATA									
41		BASE POWER PLANT PERFORMANCE DATA:									
42	i	NET THERMAL EFFICIENCY, %	N/A	N/A	N/A	38.4	25.0	50.0	46.0	46.0	N/A
43	i	BOILER EFFICIENCY, %	N/A	N/A	N/A	N/A	N/A	0.92	N/A	0.92	N/A
44	i	MAIN STEAM TEMPERATURE, C	N/A	N/A	N/A	N/A	N/A	427	N/A	N/A	N/A
45	i	MAIN STEAM PRESSURE, BAR	N/A	N/A	N/A	N/A	N/A	81.6	N/A	N/A	N/A

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	A	B	C	D	E	F	G	H	I	J	K
46	i	CONDENSER RANGE, C	N/A	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A
47	i	CONDENSER COOLING WTR PUMP HEAD, BAR	N/A	N/A	N/A	N/A	N/A	1.7	N/A	N/A	N/A
48	i	CONDENSER COOLING WTR PUMP EFFICIENCY	N/A	N/A	N/A	N/A	N/A	0.9	N/A	N/A	N/A
49	i	CONDENSING TEMPERATURE, C	N/A	N/A	N/A	N/A	N/A	37	N/A	N/A	N/A
50	i	PLANNED OUTAGE RATE	0.050	0.050	0.050	0.100	0.100	0.100	0.050	0.050	0.050
51	i	UNPLANNED OUTAGE RATE	0.050	0.050	0.050	0.110	0.110	0.110	0.050	0.050	0.050
52											
53		DUAL-PURPOSE PLT PERFORMANCE DATA:									
54		CONDENSING TEMPERATURE, C	N/A	N/A	N/A	N/A	N/A	57	N/A	N/A	N/A
55		INTERMEDIATE LOOP FLASH STM TEMP, C	92	120	122	N/A	N/A	N/A	N/A	N/A	N/A
56		INTERMEDIATE LOOP COND. RTRN TEMP, C	90	118	120	N/A	N/A	N/A	N/A	N/A	N/A
57	i	INTERMEDIATE LOOP PRESSURE LOSS, BAR	1.5	1.5	1.5	N/A	N/A	N/A	N/A	N/A	N/A
58	i	INTEMEDIATE LOOP PUMP EFFICIENCY	0.9	0.9	0.9	N/A	N/A	N/A	N/A	N/A	N/A
59											
60		MED WATER PLT PERFORMANCE DATA:									
61	i	DESALINATION TECHNOLOGY	LT-MED	LT-MED	LT-MED	N/A	N/A	LT-MED	LT-MED	LT-MED	LT-MED
62	i	PRODUCT WATER TDS, PPM	25	25	25	N/A	N/A	25	N/A	25	25
63	i	MAXIMUM BRINE TEMPERATURE, C	90	118	120	N/A	N/A	54.5	N/A	120	120
64		SEAWATER TEMPERATURE, C	27	27	27	N/A	N/A	27	N/A	27	27
65	i	MED CONDENSER RANGE, C	5	5	5	N/A	N/A	5	N/A	5	5
66	i	MED CONDENSER APPROACH, C	2	2	2	N/A	N/A	2	N/A	2	2
67		MINIMUM CONDENSING TEMPERATURE, C	34	34	34	N/A	N/A	34	N/A	34	34
68		OVERALL MED WORKING TEMPERATURE, C	56	84	86	N/A	N/A	21	N/A	86	86
69		TEMPERATURE DROP BETWEEN EFFECTS, C	2.5	2.5	2.5	N/A	N/A	2.5	N/A	2.5	2.5
70		NUMBER OF EFFECTS	24	35	36	N/A	N/A	9	N/A	36	36
71		GOR, kg PRODUCT/kg STEAM	16.1	20.2	20.4	N/A	N/A	8.1	N/A	20.4	20.4
72	i	UNIT SIZE, CU.M/D	48,000	48,000	48,000	N/A	N/A	48,000	N/A	24,000	48,000
73		SEAWATER/PRODUCT FLOW RATIO	6.4	5.1	5.1	N/A	N/A	12.8	N/A	5.1	5.1
74	i	SEAWATER HEAD + PRESS LOSS, BAR	1.7	1.7	1.7	N/A	N/A	1.7	N/A	1.7	1.7
75	i	SEAWATER PUMP EFFICIENCY	0.9	0.9	0.9	N/A	N/A	0.9	N/A	0.9	0.9
76	i	WATER PLANT SPEC. PWR USE kWe/CU.M/D	0.083	0.083	0.083	N/A	N/A	0.083	N/A	0.083	0.083
77	i	WTR PLT PLANNED OUTAGE RATE	0.030	0.030	0.030	N/A	N/A	0.030	N/A	0.030	0.030
78	i	WTR PLT UNPLANNED OUTAGE RATE	0.065	0.065	0.065	N/A	N/A	0.065	N/A	0.065	0.065
79		BACKUP HEAT SOURCE SIZE, MWt	100.00	80.00	64.00	N/A	N/A	199.76	N/A	27.55	80.00
80	i	BACKUP HEAT SOURCE AVAILABILITY	0.9	0.9	0.9	N/A	N/A	0.9	N/A	0.9	0.9
81											
82		MEMBRANE WATER PLT PERFORMANCE DATA:									
83	i	NO. STAGES TO MEET WATER STANDARD				1	1	1	1	1	
84		SEAWATER TDS, PPM	N/A	N/A	N/A	38,500	38,500	38,500	38,500	38,500	N/A
85	i	RO PRODUCT WATER TDS, PPM	N/A	N/A	N/A	270	270	270	270	270	N/A
86		WATER FLUX INCREASE FACTOR FROM TEMP	N/A	N/A	N/A	1.1	1.1	1	1	1.1	N/A
87		OUTPUT PER UNIT, CU.M/D	N/A	N/A	N/A	26,400	26,400	24,000	24,000	26,400	N/A
88		RECOVERY RATIO	N/A	N/A	N/A	0.55	0.55	0.5	0.5	0.5	N/A
89	i	SEAWATER PUMP HEAD, BAR	N/A	N/A	N/A	1.7	1.7	1.7	1.7	1.7	N/A
90	i	SEAWATER PUMP EFFICIENCY	N/A	N/A	N/A	0.9	0.9	0.9	0.9	0.9	N/A
91	i	BOOSTER PUMP HEAD, BAR	N/A	N/A	N/A	3.3	3.3	3.3	3.3	3.3	N/A
92	i	BOOSTER PUMP EFFICIENCY	N/A	N/A	N/A	0.9	0.9	0.9	0.9	0.9	N/A
93	i	STAGE 1 HIGH HD PUMP PRESS RISE, BAR	N/A	N/A	N/A	82	82	82	82	82	N/A
94	i	STAGE 1 HIGH HEAD PUMP EFFICIENCY	N/A	N/A	N/A	0.85	0.85	0.85	0.85	0.85	N/A
95	i	STG 1 HYDRAULIC COUPLING EFFICIENCY	N/A	N/A	N/A	0.965	0.965	0.965	0.965	0.965	N/A

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	A	B	C	D	E	F	G	H	I	J	K
96	I	ENERGY RECOVERY EFFICENCY	N/A	N/A	N/A	0.9	0.9	0.9	0.9	0.9	N/A
97	I	*STG 2 HYDRAULIC COUPLING EFFICIENCY*	N/A	N/A	N/A	0.965	0.965	0.965	0.965	0.965	N/A
98	I	STAGE 2 HIGH HD PUMP PRESS RISE, BAR	N/A	N/A	N/A	0	0	0	0	0	N/A
99	I	STAGE 2 HIGH HEAD PUMP EFFICIENCY	N/A	N/A	N/A	0.9	0.9	0.9	0.9	0.9	N/A
100	I	OTHER SPECIFIC POWER USE, kWe/CU M/D	N/A	N/A	N/A	0.0408	0.0408	0.0408	0.0408	0.0408	N/A
101	I	RO PLANT AVAILABILITY	N/A	N/A	N/A	0.91	0.91	0.91	0.91	0.91	N/A
102											
103		COST INPUT DATA									
104											
105		*POWER PLANT COST DATA:*									
106	I	SPEC CONSTR COST, $/kWe ($/kWt)	930	875	1266	2700	2000	650	1000	1000	400
107		ADDITIONL CONSTR COST, $/kWe ($/kWt)	93	88	127	270	200	65	100	100	40
108		*TOTAL CONSTR COST, $/kWe ($/kWt)*	1023	963	1393	2970	2200	715	1100	1100	440
109	I	CONSTRUCTION LEAD TIME, MONTHS	36	36	36	24	48	36	18	18	18
110	I	SPECIFIC O&M COST, $/MWeh ($/MWth)	2.31	5.72	4.18	11.96	8.80	5.50	7.70	7.70	13.20
111	I	GAS PRICE AT STARTUP, $/BOE	N/A	N/A	N/A	N/A	N/A	15.50	15.50	15.50	15.50
112	I	SPECIFIC FUEL COST, $/MWeh ($/MWth)	3.27	5.00	3.91	25.00	16.80	18.82	20.46	20.46	9.41
113		LEVELIZED ANNUAL DECOMM COST, M$	0.26	0.21	0.17	0.34	0.18	0.00	0.00	0.00	0.00
114	I	FUEL ANNUAL REAL ESCALATION, %	0	0	0	0	0	2	2	2	2
115											
116		*THERMAL WATER PLANT COST DATA:*									
117	I	CORRECTION FACTOR FOR UNIT SIZE	0.9	0.9	0.9	N/A	N/A	0.9	N/A	0.9	0.9
118	I	BASE UNIT COST, $/CU M/D	1680	1680	1680	N/A	N/A	1440	N/A	1680	1680
119		INTERMEDIATE LOOP UNIT COST, $/CU M/D	68	55	54	N/A	N/A	0	N/A	0	0
120	I	WATER PLT COST CONTG'CY FACTOR	0.10	0.10	0.10	N/A	N/A	0.10	N/A	0.10	0.10
121	I	WATER PLT OWNERS COST FACTOR	0.05	0.05	0.05	N/A	N/A	0.05	N/A	0.05	0.05
122	I	WATER PLT LEAD TIME,MONTHS	24	24	24	N/A	N/A	24	N/A	24	24
123	I	AVERAGE MANAGEMENT SALARY, $/YR	66000	66000	66000	N/A	N/A	66000	N/A	66000	66000
124	I	*AVERAGE LABOR SALARY, $/YR*	29700	29700	29700	N/A	N/A	29700	N/A	29700	29700
125	I	SPECIFIC O&M SPARE PARTS COST, $/CU M	0.04	0.04	0.04	N/A	N/A	0.04	N/A	0.04	0.04
126	I	SPECIFIC O&M CHEM COST, $/CU M	0.02	0.02	0.02	N/A	N/A	0.02	N/A	0.02	0.02
127	I	WATER PLT O&M INS COST,% BASE CAP	0.50	0.50	0.50	N/A	N/A	0.50	N/A	0.50	0.50
128	I	BACKUP HEAT SOURCE UNIT COST, $/MWt	50000	50000	50000	N/A	N/A	55000	N/A	55000	55000
129											
130		MEMBRANE WATER PLANT COST DATA.									
131	I	BASE UNIT COST, $/CU M/D	N/A	N/A	N/A	1023	1023	1125	1125	1023	N/A
132	I	WATER PLT COST CONTG'CY FACTOR	N/A	N/A	N/A	0.10	0.10	0.10	0.10	0.10	N/A
133	I	WATER PLT OWNERS COST FACTOR	N/A	N/A	N/A	0.05	0.05	0.05	0.05	0.05	N/A
134	I	WATER PLT LEAD TIME,MONTHS	N/A	N/A	N/A	24	24	24	24	24	N/A
135	I	*AVERAGE MANAGEMENT SALARY, $/YR*	N/A	N/A	N/A	66000	66000	66000	66000	66000	N/A
136	I	AVERAGE LABOR SALARY, $/YR	N/A	N/A	N/A	29700	29700	29700	29700	29700	N/A
137	I	O&M MEMBRANE REPLACEMENT COST, $/CU M	N/A	N/A	N/A	0.11	0.11	0.12	0.12	0.11	N/A
138	I	O&M SPARE PARTS COST, $/CU M	N/A	N/A	N/A	0.03	0.03	0.03	0.03	0.03	N/A
139	I	SPECIFIC CHEMICAL COST, $/CU M	N/A	N/A	N/A	0.06	0.06	0.07	0.07	0.06	N/A
140	I	WATER PLT O&M INS COST,% BASE CAP	N/A	N/A	N/A	0.50	0.50	0.50	0.50	0.50	N/A
141											
142		ECONOMIC PARAMETERS INPUT DATA									
143											
144		CASE 1: 5% INTEREST RATE									
145	I	AFUDC RATE, %/YR	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

	A	B	C	D	E	F	G	H	I	J	K
146		LN-94$ FIXED CHARGE RATE, %	6.51	6.51	6.51	6.51	6.51	6.51	6.51	6.51	6.51
147	i	PURCHASED ELECTRICITY COST, $/kWh	0.04	0.04	0.04	N/A	N/A	N/A	N/A	N/A	0.04
148											
149		CASE 2: 8% INTEREST RATE									
150	i	AFUDC RATE, %/YR	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
151		LN-94$ FIXED CHARGE RATE, %	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88
152	i	PURCHASED ELECTRICITY COST, $/kWh	0.05	0.05	0.05	N/A	N/A	N/A	N/A	N/A	0.05
153											
154		CASE 3: 10% INTEREST RATE									
155	i	AFUDC RATE, %/YR	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
156		LN-94$ FIXED CHARGE RATE, %	10.61	10.61	10.61	10.61	10.61	10.61	10.61	10.61	10.61
157	i	PURCHASED ELECTRICITY COST, $/kWh	0.06	0.06	0.06	N/A	N/A	N/A	N/A	N/A	0.06
158											
159		PERFORMANCE CALCULATIONS									
160											
161		SINGLE-PURPOSE PLT PERFORMANCE:									
162		THERMAL POWER, MWt	100	80	64	125	100	400	54	54	80
163		PLANT GROSS OUTPUT, MWe	N/A	N/A	N/A	51	26	211	26	26	N/A
164		PLANT AUX LOADS, MWe	1.0	0.8	0.6	2.5	1.3	10.5	0.5	0.5	0.8
165		CONDENSER COOLING WTR FLOW, kg/s	N/A	N/A	N/A	N/A	N/A	5332	N/A	N/A	N/A
166		CONDENSER COOLING WTR PUMP POWER, MWe	N/A	N/A	N/A	N/A	N/A	1.06	N/A	N/A	N/A
167		REJECT HEAT LOAD, MWt	N/A	N/A	N/A	N/A	N/A	189.5	N/A	N/A	N/A
168		TURBINE EXHAUST FLOW, kg/s	N/A	N/A	N/A	N/A	N/A	82.4	N/A	N/A	N/A
169		OPERATING AVAILABILITY	0.903	0.903	0.903	0.801	0.801	0.801	0.903	0.903	0.903
170											
171		DUAL-PURPOSE POWER PLANT PERFORMANCE:									
172		LOST SHAFTWORK, MWs	N/A	N/A	N/A	N/A	N/A	10.3	N/A	N/A	N/A
173		LOST ELECTRICITY PRODUCTION, MWe	N/A	N/A	N/A	N/A	N/A	10.2	N/A	0.00	N/A
174		NET ELECTRICITY PRODUCED, MWe	N/A	N/A	N/A	N/A	N/A	189.8	25.0	25.0	N/A
175		TOTAL HEAT TO WTR PLT, MWt	100	80	64	N/A	N/A	200	N/A	28	80
176		BACKPRESSURE TURB. EXHAUST FLOW, kg/s	N/A	N/A	N/A	N/A	N/A	86.9	N/A	N/A	N/A
177		INTERMEDIATE LOOP FLOW RATE, kg/s	11962	9569	7656	N/A	N/A	N/A	N/A	N/A	N/A
178		INTERMEDIATE LOOP PUMPING POWER, MWe	2.10	1.68	1.35	N/A	N/A	N/A	N/A	N/A	N/A
179		FLASH STEAM FLOW TO MED, kg/s	43	34	28	N/A	N/A	86	N/A	12	34
180											
181		THERMAL WATER PLANT PERFORMANCE:									
182		MAXIMUM WATER PLT CAPACITY, CU M/DAY	60,142	60,123	48,649	N/A	N/A	60,128	N/A	20,942	60,811
183		NUMBER OF UNITS	2	2	2	N/A	N/A	2	N/A	1	2
184		SEAWATER FLOW, kg/s	4,461	3,569	2,855	N/A	N/A	8,912	N/A	1,229	3,569
185		INCREMENTAL SEAWATER PUMPING PWR, MWe	0.89	0.71	0.57	N/A	N/A	0.71	N/A	0.25	0.71
186		WATER PLANT INTERNAL POWER USE, MWe	4.99	4.99	4.04	N/A	N/A	4.99	N/A	1.74	5.05
187		WTR PLT+INT.LOOP+SEAWTR PUMP PWR, MWe	7.99	7.39	5.95	N/A	N/A	5.70	N/A	1.98	5.76
188		WTR PLT OPERATING AVAILABILITY	0.907	0.907	0.907	N/A	N/A	0.907	N/A	0.907	0.907
189		COMBINED HEAT SOURCE AVAILABILITY	0.99	0.99	0.99	N/A	N/A	0.98	N/A	0.99	0.99
190		COMBINED PWR/WTR PLT CAPACITY FACTOR	0.898	0.898	0.898	N/A	N/A	0.889	N/A	0.898	0.898
191		ANNUAL WATER PRODUCTION, CU M/YR	19,715,100	19,708,754	15,947,468	N/A	N/A	19,508,526	N/A	6,865,141	19,934,336
192		AVRG DAILY WATER PRODUCTION, CU M/D	54,014	53,997	43,692	N/A	N/A	53,448	N/A	18,809	54,615
193											
194		RO WATER PLANT PERFORMANCE:									
195		PRODUCTION CAPACITY, CU M/DAY	N/A	N/A	N/A	60000	60000	60128	60000	39058	N/A

	A	B	C	D	E	F	G	H	I	J	K
196		NUMBER OF RO UNITS	N/A	N/A	N/A	3	3	3	3	2	N/A
197		SEAWATER FLOW, kg/s	N/A	N/A	N/A	1263	1263	1392	1389	904	N/A
198		STAND-ALONE SEAWATER PUMPING PWR, MWe	N/A	N/A	N/A	N/A	N/A	0 28	0 28	N/A	N/A
199		CONTIGUOUS SEAWATER PUMPING PWR, MWe	N/A	N/A	N/A	0 00	0 00	0 00	0 00	0 00	N/A
200		BOOSTER PUMP POWER, MWe	N/A	N/A	N/A	0 49	0 49	0 54	0 54	0 35	N/A
201		STAGE 1 HIGH HEAD PUMP POWER, MWe	N/A	N/A	N/A	13 33	13 33	14 69	14 66	9 54	N/A
202		ENERGY RECOVERY, MWe	N/A	N/A	N/A	4 25	4 25	5 21	5 19	3 38	N/A
203		STAGE 2 HIGH HEAD PUMP POWER MWe	N/A	N/A	N/A	0 00	0 00	0 00	0 00	0 00	N/A
204		OTHER POWER, MWe	N/A	N/A	N/A	2 23	2 23	2 45	2 45	1 45	N/A
205		TOTAL STAND-ALONE POWER USE, MWe	N/A	N/A	N/A	N/A	N/A	12 75	12 73	N/A	N/A
206		TOTAL CONTIGUOUS POWER USE, MWe	N/A	N/A	N/A	11 79	11 79	12 48	N/A	7 96	N/A
207		ANNUAL AVG WATER PRODUCTION CU M/YR	N/A	N/A	N/A	19 929 000	19 929,000	19 971,566	19,929,000	12 972 951	N/A
208		AVG DAILY WATER PRODUCTION, CU M/DAY	N/A	N/A	N/A	54 600	54 600	54,717	54,600	35 542	N/A
209		SPEC (S-A) PWR CONSUMPTION kWh/CU M	N/A	N/A	N/A	N/A	N/A	5 09	5 09	N/A	N/A
210		SPEC (CONT) PWR CONSUMPTION kWh/CU M	N/A	N/A	N/A	4 72	4 72	4 98	N/A	4 89	N/A
211		NET PWR PLNT SALEABLE PWR (S A) MWe	N/A	N/A	N/A	N/A	N/A	187 25	12 27	N/A	N/A
212		NET PWR PLNT SALEABLE PWR (CONT), MWe	N/A	N/A	N/A	36 21	13 21	187 52	N/A	N/A	N/A
213											
214		COST CALCULATIONS									
215											
216		THERMAL WATER PLANT COSTS:									
217		NUMBER OF UNITS	2 00	2 00	2 00	N/A	N/A	2 00	N/A	1 00	2 00
218		CORRECTION FACTOR FOR NO OF UNITS	0 983	0 983	0 983	N/A	N/A	0 983	N/A	1 009	0 983
219		WATER PLT SPECIFIC BASE COST,$/CU M/D	1487	1487	1487	N/A	N/A	1275	N/A	1525	1487
220		INC IN/OUTFALL SPEC BS CT, $/CU M/D	285	250	270	N/A	N/A	115	N/A	378	247
221		INTERMEDIATE LOOP COST, $/CU M/D	68	55	54	N/A	N/A	0	N/A	0	0
222		TOTAL SPECIFIC BASE COST, $/CU M/D	1840	1791	1811	N/A	N/A	1389	N/A	1903	1734
223		NUMBER OF MANAGEMENT PERSONNEL	6	6	5	N/A	N/A	6	N/A	5	6
224		WATER PLT O&M MGMT COST,M$/Y	0 40	0 40	0 33	N/A	N/A	0 40	N/A	0 33	0 40
225		NUMBER OF LABOR PERSONNEL	27	27	24	N/A	N/A	27	N/A	17	27
226		WATER PLT O&M LABOR COST,M$/Y	0 79	0 79	0 72	N/A	N/A	0 79	N/A	0 52	0 79
227		WATER PLT ADJUSTED BASE COST M$	110 68	107 68	88 08	N/A	N/A	83 53	N/A	39 86	105 43
228		BACKUP HEAT SOURCE BASE COST, M$	5 00	4 00	3 20	N/A	N/A	10 99	N/A	1 52	4 40
229		TOTAL WATER PLANT BASE COST, M$	115 68	111 68	91 28	N/A	N/A	94 51	N/A	41 37	109 83
230		WATER PLT OWNERS COST M$	5 78	5 58	4 56	N/A	N/A	4 73	N/A	2 07	5 49
231		WATER PLT CONTINGENCY ,M$	12 15	11 73	9 58	N/A	N/A	9 92	N/A	4 34	11 53
232		WATER PLT TOT CONSTRUCTION COST M$	133 61	128 99	105 43	N/A	N/A	109 16	N/A	47 78	126 85
233		WATER PLT O&M COST,M$/YR	2 92	2 91	2 45	N/A	N/A	2 77	N/A	1 46	2 91
234											
235		RO WATER PLANT COSTS,									
236		NUMBER OF UNITS	N/A	N/A	N/A	3 00	3 00	3 00	3 00	2 00	N/A
237		CORRECTION FACTOR FOR NO OF UNITS	N/A	N/A	N/A	0 959	0 959	0 959	0 959	0 983	N/A
238		PROCESS PLT SPECIFIC COST,$/CU M/D	N/A	N/A	N/A	981	981	1079	1079	1006	N/A
239		STND-ALN IN/OUTFALL SPEC CT, $/CU M/D	N/A	N/A	N/A	N/A	N/A	142	142	N/A	N/A
240		STND ALN WTR PLNT SPEC CT, $/CU M/D	N/A	N/A	N/A	N/A	N/A	1220	1221	N/A	N/A
241		NUMBER OF MANAGEMENT PERSONNEL	N/A	N/A	N/A	5	5	6	6	5	N/A
242		O&M MGMT COST,M$/Y	N/A	N/A	N/A	0 33	0 33	0 40	0 40	0 33	N/A
243		NUMBER OF LABOR PERSONNEL	N/A	N/A	N/A	24	24	27	27	20	N/A
244		O&M LABOR COST,M$/Y	N/A	N/A	N/A	0 72	0 72	0 79	0 79	0 60	N/A
245		STND-ALN WTR PLT ADJUSTED BASE CT M$	N/A	N/A	N/A	N/A	N/A	73 38	73 23	N/A	N/A

	A	B	C	D	E	F	G	H	I	J	K
246		CONTIGUOUS WTR PLT ADJUSTED BS CT,M$	N/A	N/A	N/A	58.83	58.83	64.85	N/A	39.28	N/A
247		WATER PLT OWNERS COST,M$	N/A	N/A	N/A	2.94	2.94	3.67	3.66	1.96	N/A
248		WATER PLT CONTINGENCY ,M$	N/A	N/A	N/A	6.18	6.18	7.71	7.69	4.12	N/A
249		STND-ALN WTR PLT TOT CONSTRUCT CT, M$	N/A	N/A	N/A	N/A	N/A	84.76	84.58	N/A	N/A
250		CONTIGUOUS WTR PLT TOT CONSTR CT, M$	N/A	N/A	N/A	67.95	67.95	76.23	N/A	45.37	N/A
251		WATER PLT O&M COST,M$/YR	N/A	N/A	N/A	5.33	5.33	5.95	5.93	3.72	N/A
252											
253		ECONOMIC EVALUATIONS									
254											
255		CASE 1: 6% INTEREST RATE									
256		-POWER PLANT COST									
257		TOTAL CONSTRUCTION COST, M$	102.30	77.00	89.13	142.56	55.00	143.00	27.50	27.50	35.20
258		AFUDC, M$	7.77	5.85	6.77	7.13	5.64	10.86	1.02	1.02	1.31
259		TOTAL PLANT INVESTMENT, M$	110.07	82.85	95.89	149.69	60.64	153.86	28.52	28.52	36.51
260		LEVELIZED ANNUAL CAPITAL COST, M$	7.16	5.39	6.24	9.74	3.94	10.01	1.86	1.86	2.38
261		FUEL LEVELIZED FACTOR	1.00	1.00	1.00	1.00	1.00	1.60	1.60	1.60	1.60
262		ANNUAL FUEL COST, M$	2.59	3.16	1.98	8.42	2.95	42.19	6.46	6.46	9.51
263		ANNUAL O&M COST, M$	1.83	3.62	2.11	4.03	1.54	7.72	1.52	1.52	8.35
264		ELEC. PWR COST (HEAT ONLY), M$/YR	0.32	0.25	0.20	N/A	N/A	N/A	N/A	N/A	0.25
265		DECOMMISSIONING COST, M$	0.26	0.21	0.17	0.34	0.18	0.00	0.00	0.00	0.00
266		TOTAL ANNUAL REQUIRED REVENUE, M$	12.15	12.63	10.70	22.52	8.61	59.92	9.84	9.84	20.48
267		ANNUAL ELECTRICITY PRODUCTION, kWh	790,590,000	632,472,000	505,977,600	336,804,480	175,419,000	1,403,352,000	197,647,500	197,647,500	632,472,000
268		LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	0.067	0.049	0.043	0.050	0.050	N/A
269											
270		-THERMAL (MED) PLANT:									
271		ANNUAL WATER PROD, CU.M/YR	19,715,100	19,708,754	15,947,468	N/A	N/A	19,508,526	N/A	6,865,141	19,934,336
272		TOTAL CONSTRUCTION COST, M$	133.61	128.99	105.43	N/A	N/A	109.16	N/A	47.78	126.85
273		AFUDC ,M$	6.68	6.45	5.27	N/A	N/A	5.46	N/A	2.39	6.34
274		TOTAL INVESTMENT ,M$	140.29	135.44	110.70	N/A	N/A	114.62	N/A	50.17	133.19
275		WATER CT, FIXED CHARGE, M$/YR	9.13	8.81	7.20	N/A	N/A	7.46	N/A	3.26	8.66
276		WATER CT, HEAT CHARGE, M$/YR	12.15	12.63	10.70	N/A	N/A	3.39	N/A	0.00	20.48
277		WATER CT, ELEC CHARGE, M$/YR	2.51	2.32	1.87	N/A	N/A	1.90	N/A	0.78	1.81
278		WATER CT, O&M CHARGE, M$/YR	2.92	2.91	2.45	N/A	N/A	2.77	N/A	1.46	2.91
279		TOTAL WATER COST, $/CU.M	1.35	1.35	1.39	N/A	N/A	0.80	N/A	0.80	1.70
280											
281		-STAND-ALONE RO PLANT:									
282		SPECIFIED OUTPUT									
283		ANNUAL WATER PROD, CU.M/YR	N/A	N/A	N/A	N/A	N/A	19,971,566	19,929,000	N/A	N/A
284		TOTAL CONSTRUCTION COST ,M$	N/A	N/A	N/A	N/A	N/A	84.76	84.58	N/A	N/A
285		AFUDC ,M$	N/A	N/A	N/A	N/A	N/A	4.24	4.23	N/A	N/A
286		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	N/A	N/A	88.99	88.81	N/A	N/A
287		WATER CT, FIXED CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	5.79	5.78	N/A	N/A
288		WATER CT, ELEC CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	4.34	5.05	N/A	N/A
289		WATER CT, O&M CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	5.95	5.93	N/A	N/A
290		TOTAL WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	0.80	0.84	N/A	N/A
291		-CONTIGUOUS RO PLANT:									
292		ANNUAL WATER PROD, CU.M/YR	N/A	N/A	N/A	19,929,000	19,929,000	19,971,566	N/A	12,972,951	N/A
293		TOTAL CONSTRUCTION COST ,M$	N/A	N/A	N/A	67.95	67.95	76.23	N/A	45.37	N/A
294		AFUDC ,M$	N/A	N/A	N/A	3.40	3.40	3.81	N/A	2.27	N/A
295		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	71.35	71.35	80.04	N/A	47.64	N/A

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	A	B	C	D	E	F	G	H	I	J	K
296		WATER CT, FIXED CHARGE, M$/YR	N/A	N/A	N/A	4 64	4 64	5 21	N/A	3 10	N/A
297		WATER CT, ELEC CHARGE, M$/YR	N/A	N/A	N/A	6 29	4 61	4 25	N/A	3 16	N/A
298		WATER CT, O&M CHARGE, M$/YR	N/A	N/A	N/A	5 33	5 33	5 95	N/A	3 72	N/A
299		TOTAL WATER COST, $/CU M	N/A	N/A	N/A	0 82	0 73	0 77	N/A	0 77	N/A
300											
301		HYBRID MED/RO									
302		HYBRID ANNUAL WATER PRODUCTION	N/A	N/A	N/A	N/A	N/A	N/A	N/A	19 838 092	N/A
303		COMBINED WTR COST FOR HYBRID, $/CU M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0 78	N/A
304											
305		CASE 2. 8% INTEREST RATE									
306		-POWER PLANT COST									
307		*TOTAL CONSTRUCTION COST, M$*	*102 30*	*77 00*	*89 13*	*142 56*	55 00	143 00	27 50	27 50	35 20
308		AFUDC, M$	12 52	9 42	10 91	11 40	9 15	17 50	1 63	1 63	2 09
309		TOTAL PLANT INVESTMENT, M$	114 82	86 42	100 03	153 96	64 15	160 50	29 13	29 13	37 29
310		LEVELIZED ANNUAL CAPITAL COST, M$	10 20	7 68	8 89	13 68	5 70	14 26	2 59	2 59	3 31
311		FUEL LEVELIZED FACTOR	1 00	1 00	1 00	1 00	1 00	1 54	1 54	1 54	1 54
312		ANNUAL FUEL COST, M$	2 59	3 16	1 98	8 42	2 95	40 66	6 23	6 23	9 16
313		ANNUAL O&M COST, M$	1 83	3 62	2 11	4 03	1 54	7.72	1 52	1 52	8 35
314		DECOMMISSIONING COST, M$	0 26	0 21	0 17	0 34	0 18	0 00	0 00	0 00	0 00
315		ELEC. PWR COST (HEAT ONLY), M$/YR	0 40	0 32	0 25	N/A	N/A	N/A	N/A	N/A	0 32
316		TOTAL ANNUAL REQUIRED REVENUE, M$	15 27	14,98	13 40	26 46	10 36	62 64	10 33	10 33	21 14
317		ANNUAL ELECTRICITY PRODUCTION, KWH	N/A	N/A	N/A	336 804,480	175 419,000	1,403 352,000	197,647,500	197,647,500	N/A
318		LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	0 079	0 059	0 045	0 052	0 052	N/A
319											
320		-THERMAL (MED) PLANT:									
321		TOTAL CONSTRUCTION COST, M$	133 61	128 99	105 43	N/A	N/A	109 16	N/A	47 78	126 85
322		AFUDC, M$	10 69	10 32	8 43	N/A	N/A	8 73	N/A	3 82	10 15
323		TOTAL WATER PLANT INVESTMENT, M$	144 30	139 31	113 87	N/A	N/A	117 90	N/A	51 61	137 00
324		WATER CT, FIXED CHARGE, M$/YR	12 82	12 37	10 11	N/A	N/A	10 47	N/A	4 58	12 17
325		WATER CT, HEAT CHARGE, M$/YR	15 27	14 98	13 40	N/A	N/A	3 54	N/A	0 00	21 14
326		WATER CT, ELEC CHARGE, M$/YR	3 14	2 91	2 34	N/A	N/A	1 98	N/A	0 82	2 27
327		WATER CT, O&M CHARGE, M$/YR	2 92	2 91	2 45	N/A	N/A	2 77	N/A	1 46	2 91
328		TOTAL WATER COST, $/CU M	1 73	1 68	1 78	N/A	N/A	0 96	N/A	1 00	1 93
329											
330		-STAND-ALONE RO PLANT:									
331		TOTAL CONSTRUCTION COST ,M$	N/A	N/A	N/A	N/A	N/A	84 76	84 58	N/A	N/A
332		AFUDC ,M$	N/A	N/A	N/A	N/A	N/A	6 78	6 77	N/A	N/A
333		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	N/A	N/A	91 54	91 35	N/A	N/A
334		WATER CT, FIXED CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	8 13	8 11	N/A	N/A
335		WATER CT, ELEC CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	4 54	5 31	N/A	N/A
336		WATER CT, O&M CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	5 95	5 93	N/A	N/A
337		TOTAL WATER COST, $/CU M	N/A	N/A	N/A	N/A	N/A	0 93	0 97	N/A	N/A
338		-CONTIGUOUS RO PLANT:									
339		TOTAL CONSTRUCTION COST ,M$	N/A	N/A	N/A	67 95	67 95	76 23	N/A	45 37	N/A
340		AFUDC ,M$	N/A	N/A	N/A	5 44	5 44	6 10	N/A	3 63	N/A
341		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	73 39	73 39	82 33	N/A	49 00	N/A
342		WATER CT, FIXED CHARGE, M$/YR	N/A	N/A	N/A	6 52	6 52	7 31	N/A	4 35	N/A
343		WATER CT, ELEC CHARGE, M$/YR	N/A	N/A	N/A	7 38	5 55	4 44	N/A	3 32	N/A
344		WATER CT, O&M CHARGE, M$/YR	N/A	N/A	N/A	5 33	5 33	5 95	N/A	3 72	N/A
345		TOTAL WATER COST $/CU M	N/A	N/A	N/A	0 96	0 87	0 89	N/A	0 88	N/A

	A	B	C	D	E	F	G	H	I	J	K
346											
347		HYBRID MED/RO									
348		HYBRID ANNUAL WATER PRODUCTION	N/A	N/A	N/A	N/A	N/A	N/A	N/A	19 838,092	N/A
349		COMBINED WTR COST FOR HYBRID, $/CU M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0 92	N/A
350											
351		CASE 3. 10% INTEREST RATE									
352		POWER PLANT COST									
353		TOTAL CONSTRUCTION COST, M$	102 30	77 00	89 13	142 56	55 00	143 00	27 50	27 50	35 20
354		AFUDC, M$	15 72	11 83	13 70	14 26	11 55	21 98	2 04	2 04	2 61
355		TOTAL PLANT INVESTMENT, M$	118 02	88 83	102 82	156 82	66 55	164 98	29 54	29 54	37 81
356		LEVELIZED ANNUAL CAPITAL COST, M$	12 52	9 42	10 91	16 63	7 06	17 50	3 13	3 13	4 01
357		FUEL LEVELIZED FACTOR	1 00	1 00	1 00	1.00	1 00	1 51	1 51	1 51	1 51
358		ANNUAL FUEL COST, M$	2 59	3 16	1 98	8 42	2 95	39 81	6 09	6 09	8 97
359		ANNUAL O&M COST, M$	1 83	3 62	2 11	4 03	1 54	7 72	1 52	1 52	8 35
360		DECOMMISSIONING COST, M$	0 26	0 21	0 17	0 34	0 18	0 00	0 00	0 00	0 00
361		ELEC PWR COST (HEAT ONLY), M$/YR	0 47	0 38	0 30	N/A	N/A	N/A	N/A	N/A	0 38
362		TOTAL ANNUAL REQUIRED REVENUE, M$	17 67	16 79	15 47	29 42	11 73	65 02	10 75	10 75	21 71
363		ANNUAL ELECTRICITY PRODUCTION, KWH	N/A	N/A	N/A	336 804 480	175 419 000	1 403,352,000	197,647,500	197,647,500	N/A
364		LEVELIZED POWER COST $/kWh	N/A	N/A	N/A	0 087	0 067	0 046	0 054	0 054	N/A
365											
366		-THERMAL (MED) PLANT:									
367		TOTAL CONSTRUCTION COST	133 61	128 99	105 43	N/A	N/A	109 16	N/A	47 78	126 85
368		AFUDC ,M$	13 36	12 90	10 54	N/A	N/A	10 92	N/A	4 78	12 68
369		TOTAL INVESTMENT ,M$	146 97	141 89	115 98	N/A	N/A	120 08	N/A	52 56	139 53
370		WATER CT, FIXED CHARGE, M$/YR	15 59	15 05	12 30	N/A	N/A	12 74	N/A	5 58	14 80
371		WATER CT, HEAT CHARGE, M$/YR	17 67	16 79	15 47	N/A	N/A	3 68	N/A	0 00	21 71
372		WATER CT, ELEC CHARGE, M$/YR	3 77	3 49	2 81	N/A	N/A	2 06	N/A	0 85	2 72
373		WATER CT, O&M CHARGE, M$/YR	2 92	2 91	2 45	N/A	N/A	2 77	N/A	1 46	2 91
374		TOTAL WATER COST, $/CU M	2 03	1 94	2 07	N/A	N/A	1 09	N/A	1 15	2 11
375											
376		-STAND-ALONE RO PLANT.									
377		TOTAL CONSTRUCTION COST, M$	N/A	N/A	N/A	N/A	N/A	84 76	84 58	N/A	N/A
378		AFUDC, M$	N/A	N/A	N/A	N/A	N/A	8 48	8 46	N/A	N/A
379		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	N/A	N/A	93 23	93 04	N/A	N/A
380		WATER CT, FIXED CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	9 89	9 87	N/A	N/A
381		WATER CT, ELEC CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	4 71	5 52	N/A	N/A
382		WATER CT, O&M CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	5 95	5 93	N/A	N/A
383		TOTAL WATER COST, $/CU M	N/A	N/A	N/A	N/A	N/A	1 03	1 07	N/A	N/A
384		-CONTIGUOUS RO PLANT:									
385		TOTAL CONSTRUCTION COST, M$	N/A	N/A	N/A	67 95	67 95	76 23	N/A	45 37	N/A
386		AFUDC, M$	N/A	N/A	N/A	6 80	6 80	7 62	N/A	4 54	N/A
387		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	74 75	74 75	83 85	N/A	49 91	N/A
388		WATER CT, FIXED CHARGE, M$/YR	N/A	N/A	N/A	7 93	7 93	8 89	N/A	5 29	N/A
389		WATER CT, ELEC CHARGE, M$/YR	N/A	N/A	N/A	8 21	6 28	4 61	N/A	3 45	N/A
390		WATER CT, O&M CHARGE, M$/YR	N/A	N/A	N/A	5 33	5 33	5 95	N/A	3 72	N/A
391		TOTAL WATER COST, $/CU M	N/A	N/A	N/A	1 08	0 98	0 97	N/A	0 96	N/A
392											
393		HYBRID MED/RO									
394		HYBRID ANNUAL WATER PRODUCTION	N/A	N/A	N/A	N/A	N/A	N/A	N/A	19 838,092	N/A
395		COMBINED WTR COST FOR HYBRID, $/CU M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1 03	N/A

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	A	B	C	D	E	F	G	H	I	J	K
396											
397		SUMMARY									
398											
399		CASE	Tunisia-1	Tunisia-2	Tunisia-3	Tunisia-4	Tunisia-5	Tunisia-6	Tunisia-7	Tunisia-8	Tunisia-9
400		PLANT TYPE	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	FOSSIL	FOSSIL	FOSSIL	FOSSIL
401		PRODUCT	HEAT ONLY	HEAT ONLY	HEAT ONLY	POWER ONLY	POWER ONLY	HEAT & POWER	POWER ONLY	HEAT & POWER	HEAT ONLY
402		REFERENCE OF FLOW DIAGRAM	V	V	V	II B	II B	XIII, XIV	XVI	XVIII	IX
403		WATER PLANT TYPE	MED	MED	MED	RO	RO	MED OR RO	RO	MED/RO HYBRID	MED
404		REACTOR TYPE	THERMOS	LT-4	TRIGA	4S	CAREM-25	COMBINED CYCLE	DIESEL	DIESEL	FOSSIL BOILER
405		SELECTED NET OUTPUT, MWe (MWt)	100	80	64	48	25	200	25	25	80
406		PRODUCT DRINKING WATER STANDARD	WHO	WHO	WHO	WHO	WHO	WHO	WHO	WHO	WHO
407											
408		SUMMARY CASE 1: 5% INT & AFUDC RATE									
409		-LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	0.067	0.049	0.043	0.050	0.050	N/A
410		-PURCHASED POWER COST, $/kWh	0.04	0.04	0.04	N/A	N/A	N/A	N/A	N/A	0.04
411		-THERMAL MED PLANT (OPTIMIZED)									
412		WATER PRODUCTION CAPACITY, CU.M/D	60142	60123	48649	N/A	N/A	60128	N/A	20942	60811
413		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	184.10	N/A	N/A	N/A
414		WATER COST, $/CU.M	1.35	1.35	1.39	N/A	N/A	0.80	N/A	0.80	1.70
415		-STAND-ALONE RO PLT (MED EQ. OUTPUT)									
416		WATER PRODUCTION CAPACITY, CU.M/D	N/A	N/A	N/A	N/A	N/A	60128	60000	N/A	N/A
417		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	187.25	12.27	N/A	N/A
418		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	0.80	0.84	N/A	N/A
419		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)									
420		WATER PRODUCTION CAPACITY, CU.M/D	N/A	N/A	N/A	60000	60000	60128	N/A	39058	N/A
421		NET SALEABLE POWER, MWe	N/A	N/A	N/A	36.21	13.21	187.52	N/A	N/A	N/A
422		WATER COST, $/CU.M	N/A	N/A	N/A	0.82	0.73	0.77	N/A	0.77	N/A
423		-HYBRID COMBINED MED/RO									
424		WATER PRODUCTION CAPACITY, CU.M/D	N/A	N/A	N/A	N/A	N/A	N/A	N/A	60000	N/A
425		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15	N/A
426		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.78	N/A
427											
428		SUMMARY CASE 2: 8% INT & AFUDC RATE									
429		-LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	0.079	0.059	0.045	0.052	0.052	N/A
430		-PURCHASED POWER COST, $/kWh	0.05	0.05	0.05	N/A	N/A	N/A	N/A	N/A	0.05
431		-THERMAL MED PLANT (OPTIMIZED)									
432		WATER PRODUCTION CAPACITY, CU.M/D	60142	60123	48649	N/A	N/A	60128	N/A	20942	60811
433		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	184.10	N/A	N/A	N/A
434		WATER COST, $/CU.M	1.73	1.68	1.78	N/A	N/A	0.96	N/A	1.00	1.93
435		-STAND-ALONE RO PLT (MED EQ. OUTPUT)									
436		WATER PRODUCTION CAPACITY, CU.M/D	N/A	N/A	N/A	N/A	N/A	60128	60000	N/A	N/A
437		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	187.25	12.27	N/A	N/A
438		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	0.93	0.97	N/A	N/A
439		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)									
440		WATER PRODUCTION CAPACITY, CU.M/D	N/A	N/A	N/A	60000	60000	60128	N/A	39058	N/A
441		NET SALEABLE POWER, MWe	N/A	N/A	N/A	36.21	13.21	187.52	N/A	N/A	N/A
442		WATER COST, $/CU.M	N/A	N/A	N/A	0.96	0.87	0.89	N/A	0.88	N/A
443		-HYBRID COMBINED MED/RO									
444		WATER PRODUCTION CAPACITY, CU.M/D	N/A	N/A	N/A	N/A	N/A	N/A	N/A	60000	N/A
445		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15	N/A

	A	B	C	D	E	F	G	H	I	J	K
446		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.92	N/A
447											
448		*SUMMARY CASE 3: 10% INT & AFUDC RATE*									
449		-LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	0.087	0.067	0.046	0.054	0.054	N/A
450		-PURCHASED POWER COST, $/kWh	0.06	0.06	0.06	N/A	N/A	N/A	N/A	N/A	0.06
451		-THERMAL MED PLANT (OPTIMIZED)									
452		WATER PRODUCTION CAPACITY, CU.M/D	60142	60123	48649	N/A	N/A	60128	N/A	20942	60811
453		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	184.10	N/A	N/A	N/A
454		WATER COST, $/CU.M	2.03	1.94	2.07	N/A	N/A	1.09	N/A	1.15	2.11
455		-STAND ALONE RO PLT (MED EQ. OUTPUT)									
456		WATER PRODUCTION CAPACITY, CU.M/D	N/A	N/A	N/A	N/A	N/A	60128	60000	N/A	N/A
457		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	187.25	12.27	N/A	N/A
458		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	1.03	1.07	N/A	N/A
459		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)									
460		WATER PRODUCTION CAPACITY, CU M/D	N/A	N/A	N/A	60000	60000	60128	N/A	39058	N/A
461		NET SALEABLE POWER, MWe	N/A	N/A	N/A	36.21	13.21	187.52	N/A	N/A	N/A
462		WATER COST, $/CU.M	N/A	N/A	N/A	1.08	0.98	0.97	N/A	0.96	N/A
463		-HYBRID COMBINED MED/RO									
464		WATER PRODUCTION CAPACITY, CU M/D	N/A	N/A	N/A	N/A	N/A	N/A	N/A	60000	N/A
465		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15	N/A
466		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.03	N/A
467											
468		INVESTMENT COSTS - 8% INTEREST RATE									
469											
470		POWER PLANT									
471		SPECIFIC CONSTRUCTION COST, $/kW	1023	963	1393	2970	2200	715	1100	1100	440
472		- POWER PLANT CONSTRUCTION, M$	102	77	89	143	55	143	28	28	35
473		- POWER PLANT IDC, M$	13	9	11	11	9	17	2	2	2
474		TOTAL INVESTMENT COST, M$	115	86	100	154	64	160	29	29	37
475		SPECIFIC INVESTMENT COST, $/kW	1148	1080	1563	3208	2566	802	1165	1165	466
476											
477		POWER & THERMAL MED PLANT									
478		- POWER PLANT CONSTRUCTION, M$	102	77	89	N/A	N/A	143	N/A	28	35
479		- POWER PLANT IDC, M$	13	9	11	N/A	N/A	17	N/A	2	2
480		-PWR PLT COST PORTION OF WTR PROD M$	115	86	100	N/A	N/A	13	N/A	12	37
481		- MED PLANT CONSTRUCTION, M$	134	129	105	N/A	N/A	109	N/A	48	127
482		- MED PLANT IDC, M$	11	10	8	N/A	N/A	9	N/A	4	10
483		TOTAL INVESTMENT COST, M$	259	226	214	N/A	N/A	131	N/A	63	174
484		- MED CAPACITY, CU.M/D	60142	60123	48649	N/A	N/A	60128	N/A	20942	60811
485		SPECIFIC INVESTMENT COST, $/CU.M/D	4308	3755	4397	N/A	N/A	2173	N/A	3018	2866
486											
487		POWER & S-A RO (MED EQUIV.) PLANT									
488		- POWER PLANT CONSTRUCTION, M$	N/A	N/A	N/A	N/A	N/A	143	28	N/A	N/A
489		- POWER PLANT IDC, M$	N/A	N/A	N/A	N/A	N/A	17	2	N/A	N/A
490		-PWR PLT COST PORTION OF WTR PROD M$	N/A	N/A	N/A	N/A	N/A	10	15	N/A	N/A
491		- RO PLANT CONSTRUCTION, M$	N/A	N/A	N/A	N/A	N/A	85	85	N/A	N/A
492		- RO PLANT IDC, M$	N/A	N/A	N/A	N/A	N/A	7	7	N/A	N/A
493		TOTAL INVESTMENT COST, M$	N/A	N/A	N/A	N/A	N/A	102	106	N/A	N/A
494		- RO (MED EQUIV.) CAPACITY, CU.M/D	N/A	N/A	N/A	N/A	N/A	60128	60000	N/A	N/A
495		SPECIFIC INVESTMENT COST, $/CU.M/D	N/A	N/A	N/A	N/A	N/A	1693	1770	N/A	N/A

TUNISIA.XLS

	A	B	C	D	E	F	G	H	I	J	K
496											
497		COST SUMMARY: 8% INTEREST RATE									
498											
499		-POWER PLANT COST									
500		TOTAL PLANT INVESTMENT, M$	114 82	86 42	100 03	153 96	64 15	160 50	29 13	29 13	37 29
501		LEVELIZED ANNUAL CAPITAL COST, M$	10 20	7 68	8 89	13 68	5 70	14 26	2 59	2 59	3 31
502		TOTAL ANNUAL REQUIRED REVENUE, M$	15 27	14 98	13 40	26 46	10 36	62 64	10 33	10 33	21 14
503		LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	0 079	0 059	0 045	0 052	0 052	N/A
504											
505		-THERMAL (MED) PLANT:									
506		TOTAL WATER PLANT INVESTMENT, M$	144 30	139 31	113 87	N/A	N/A	117 90	N/A	51 61	137 00
507		WATER CT, FIXED CHARGE, $/CU M	0 65	0 63	0 63	N/A	N/A	0 54	N/A	0 67	0 61
508		WATER CT, ENERGY CHARGE, $/CU M	0 93	0 91	0 99	N/A	N/A	0 28	N/A	0 12	1 17
509		WATER CT, O&M CHARGE, $/CU M	0 15	0 15	0 15	N/A	N/A	0 14	N/A	0 21	0 15
510		TOTAL WATER COST, $/CU M	1 73	1 68	1 76	N/A	N/A	0 96	N/A	1 00	1 93
511											
512		-STAND-ALONE RO PLANT:									
513		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	N/A	N/A	91 54	91 35	N/A	N/A
514		WATER CT, FIXED CHARGE, $/CU M	N/A	N/A	N/A	N/A	N/A	0 41	0 41	N/A	N/A
515		WATER CT, ENERGY CHARGE, $/CU M	N/A	N/A	N/A	N/A	N/A	0 23	0 27	N/A	N/A
516		WATER CT, O&M CHARGE, $/CU M	N/A	N/A	N/A	N/A	N/A	0 30	0 30	N/A	N/A
517		TOTAL WATER COST, $/CU M	N/A	N/A	N/A	N/A	N/A	0 93	0 97	N/A	N/A
518											
519		-CONTIGUOUS RO PLANT:									
520		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	73 39	73 39	82 33	N/A	49 00	N/A
521		WATER CT, FIXED CHARGE, $/CU M	N/A	N/A	N/A	0 33	0 33	0 37	N/A	0 34	N/A
522		WATER CT, ENERGY CHARGE, $/CU M	N/A	N/A	N/A	0 37	0 28	0 22	N/A	0 26	N/A
523		WATER CT, O&M CHARGE, $/CU M	N/A	N/A	N/A	0 27	0 27	0 30	N/A	0 29	N/A
524		TOTAL WATER COST, $/CU M	N/A	N/A	N/A	0 96	0 87	0 89	N/A	0 88	N/A

ANNEX V

COUPLING BETWEEN SELECTED ENERGY SOURCES AND DESALINATION PROCESSES

FOR LAAYOUNE, MOROCCO (24,000 m^3/d)

(MATRIX AND SPREADSHEETS)

TABLE V.1: Laayoune, Morocco - 24,000 m^3/d

Primary Energy	Energy Cycle	Scheme	MED	Stand Alone RO	MED/VC
Nuclear	Heat Only Steam Cycle	TRIGA GEYSER SES-10	V Morocco-3 Morocco-2 Morocco-1		
Fossil	Diesel	oil/gas		XVI Morocco-5	XVIII Morocco-6
	Heat Only Boiler	oil/gas	XIX Morocco-4		
	Solar Pond	solar	XX Morocco-7		

* Data given in this table are only indicative

	A	B	C	D	E	F	G	H	I
1		IAEA DESALINATION COST ANALYSIS - REGIONAL STUDY						MOROCCO.XLS	
2		MOROCCO SITE WITH WHO WATER QUALITY STANDARD						29-Sep-94	
3		(All values in U.S. Jan.94 $)							
4									
5		SPREADSHEET ORGANIZATION:	START ROW #	END ROW #					
6									
7		PLANT CHARACTERISTICS	17	38					
8		PERFORMANCE INPUT DATA	40	101					
9		COST INPUT DATA	103	140					
10		ECONOMIC PARAMETER INPUT DATA	142	157					
11		PERFORMANCE CALCULATIONS	159	212					
12		COST CALCULATIONS	214	251					
13		ECONOMIC EVALUATIONS	253	395					
14		SUMMARY	396	524					
15	I	(I = input data)							
16		PLANT AND SITE CHARACTERISTICS							
17									
18	I	CASE	Morocco-1	Morocco-2	Morocco-3	Morocco-4	Morocco-5	Morocco 6	Morocco 7
19	I	ASSUMED LOCATION	LAAYOUNE	LAAYOUNE	LAAYOUNE	LAAYOUNE	LAAYOUNE	LAAYOUNE	LAAYOUNE
20	I	WATER DEMAND, CU M/D	24000	24000	24000	24000	24000	24000	24000
21	I	PLANT TYPE	NUCLEAR	NUCLEAR	NUCLEAR	FOSSIL	FOSSIL	FOSSIL	RENEWABLE
22	I	PRODUCT	HEAT ONLY	HEAT ONLY	HEAT ONLY	HEAT ONLY	POWER ONLY	POWER ONLY	HEAT ONLY
23	I	REFERENCE TO GENERIC CASES	V	V	V	XIX	XVI	XVII	XX
24	I	FUEL TYPE	UO2	UZrH	UZrH	GAS	OIL/GAS	OIL/GAS	SOLAR
25	I	REACTOR OR FOSSIL PLANT TYPE	SES-10	GEYSER	TRIGA	GAS BOILER	DIESEL	DIESEL	SOLAR POND
26	I	SIZE CATEGORY	SMALL	SMALL	SMALL	MEDIUM	SMALL	SMALL	SMALL
27	i	WATER PLANT TYPE	MED	MED	MED	MED	RO	MED/VC	MED
28	i	SELECTED UNIT NET OUTPUT, MWe (MWt)	10	23	36	36	25	25	50
29	i	TOTAL NET OUTPUT, MWe (MWt)	60	46	36	36	25	25	50
30	I	SERVICE YEAR	2005	2005	2005	2005	2005	2005	2005
31	i	CURRENCY REFERENCE YEAR	1994	1994	1994	1994	1994	1994	1994
32	I	SALEABLE POWER	NO	NO	NO	NO	YES	YES	NO
33	i	ASSUMED AVG COOLING WATER TEMP, C	21	21	21	21	21	21	21
34	i	MED DESIGN,COOLING WATER TEMP, C	27	27	27	27	27	27	27
35	I	RO DESIGN COOLING WATER TEMP, C	18	18	18	18	18	18	18
36	I	CONTIGUOUS RO PREHEAT TEMPERATURE, C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37	i	SEAWATER TOTAL DISSOLVED SOLIDS, PPM	38500	38500	38500	38500	38500	38500	38500
38	i	PRODUCT DRINKING WATER STANDARD	WHO	WHO	WHO	WHO	WHO	WHO	WHO
39									
40		PERFORMANCE INPUT DATA							
41		BASE POWER PLANT PERFORMANCE DATA:							
42	I	NET THERMAL EFFICIENCY, %	N/A	N/A	N/A	N/A	46.0	46.0	N/A
43	I	BOILER EFFICIENCY, %	N/A	N/A	N/A	N/A	N/A	N/A	N/A
44	i	MAIN STEAM TEMPERATURE, C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
45	I	MAIN STEAM PRESSURE, BAR	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	A	B	C	D	E	F	G	H	I
46	i	CONDENSER RANGE, C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
47	i	CONDENSER COOLING WTR PUMP HEAD, BAR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
48	i	CONDENSER COOLING WTR PUMP EFFICIENCY	N/A	N/A	N/A	N/A	N/A	N/A	N/A
49	i	CONDENSING TEMPERATURE, C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
50	i	PLANNED OUTAGE RATE	0.050	0.050	0.050	0.050	0.050	0 050	0 050
51	i	UNPLANNED OUTAGE RATE	0.050	0.050	0 050	0.050	0.050	0 050	0 050
52									
53		DUAL-PURPOSE PLT PERFORMANCE DATA:							
54		CONDENSING TEMPERATURE, C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
55		INTERMEDIATE LOOP FLASH STM TEMP, C	65	82	122	N/A	N/A	N/A	N/A
56		INTERMEDIATE LOOP COND. RTRN TEMP, C	63 0	80	120	N/A	N/A	N/A	N/A
57	i	INTERMEDIATE LOOP PRESSURE LOSS, BAR	1.50	1.50	1.50	N/A	N/A	N/A	N/A
58	i	INTEMEDIATE LOOP PUMP EFFICIENCY	0.90	0 90	0 90	N/A	N/A	N/A	N/A
59									
60		MED WATER PLT PERFORMANCE DATA:							
61	i	DESALINATION TECHNOLOGY	LT-MED	LT-MED	LT-MED	LT-MED	N/A	N/A	LT-MED
62	i	PRODUCT WATER TDS, PPM	25	25	25	25	N/A	N/A	25
63	i	MAXIMUM BRINE TEMPERATURE, C	63	80	120	120	N/A	N/A	72
64		SEAWATER TEMPERATURE, C	27	27	27	27	N/A	N/A	27
65	i	MED CONDENSER RANGE, C	5	5	5	5	N/A	N/A	5
66	i	MED CONDENSER APPROACH, C	2	2	2	2	N/A	N/A	2
67		MINIMUM CONDENSING TEMPERATURE, C	34	34	34	34	N/A	N/A	34
68		OVERALL MED WORKING TEMPERATURE, C	29	46	86	86	N/A	N/A	38
69		TEMPERATURE DROP BETWEEN EFFECTS, C	2 24	2 52	3.13	3.13	N/A	N/A	2 39
70		NUMBER OF EFFECTS	13	19	28	28	N/A	N/A	17
71		GOR, kg PRODUCT/kg STEAM	10.5	14.0	17.9	17.9	N/A	N/A	13 0
72	i	UNIT SIZE, CU.M/D	2,000	6,000	12,000	12,000	N/A	N/A	12 000
73		SEAWATER/PRODUCT FLOW RATIO	9.8	7.4	5.8	5 8	N/A	N/A	8 0
74	i	SEAWATER HEAD + PRESS LOSS, BAR	1.7	1.7	1.7	1.7	N/A	N/A	1 7
75	i	SEAWATER PUMP EFFICIENCY	0.9	0.9	0.9	0 9	N/A	N/A	0 9
76	i	WATER PLANT SPEC. PWR USE kWe/CU M/D	0 083	0.083	0 083	0 083	N/A	N/A	0 083
77	i	WTR PLT PLANNED OUTAGE RATE	0.030	0.030	0.030	0.030	N/A	N/A	0 030
78	i	WTR PLT UNPLANNED OUTAGE RATE	0.065	0.065	0.065	0.065	N/A	N/A	0 065
79		BACKUP HEAT SOURCE SIZE, MWt	60.00	46 00	36.00	36.00	N/A	N/A	50 00
80	i	BACKUP HEAT SOURCE AVAILABILITY	0.9	0.9	0 9	0.9	N/A	N/A	0 9
81									
82		RO OR MED/VC WATER PLT PERFORMANCE DATA:							
83	i	NO. STAGES TO MEET WATER STANDARD					1	1	
84		SEAWATER TDS, PPM	N/A	N/A	N/A	N/A	38,500	38,500	N/A
85	i	RO PRODUCT WATER TDS, PPM	N/A	N/A	N/A	N/A	270	270	N/A
86		WATER FLUX INCREASE FACTOR FROM TEMP	N/A	N/A	N/A	N/A	1	1	N/A
87		OUTPUT PER UNIT, CU M/D	N/A	N/A	N/A	N/A	24,000	24,000	N/A
88		RECOVERY RATIO	N/A	N/A	N/A	N/A	0.5	0 5	N/A
89	i	SEAWATER PUMP HEAD, BAR	N/A	N/A	N/A	N/A	1.7	1 7	N/A
90	i	SEAWATER PUMP EFFICIENCY	N/A	N/A	N/A	N/A	0.9	0 9	N/A
91	i	BOOSTER PUMP HEAD, BAR	N/A	N/A	N/A	N/A	3.3	3.3	N/A
92	i	BOOSTER PUMP EFFICIENCY	N/A	N/A	N/A	N/A	0.9	0.9	N/A
93	i	STAGE 1 HIGH HD PUMP PRESS RISE, BAR	N/A	N/A	N/A	N/A	82	120	N/A
94	i	STAGE 1 HIGH HEAD PUMP EFFICIENCY	N/A	N/A	N/A	N/A	0.85	0.8	N/A
95	i	STG 1 HYDRAULIC COUPLING EFFICIENCY	N/A	N/A	N/A	N/A	0.965	0 965	N/A

	A	B	C	D	E	F	G	H	I
96	i	ENERGY RECOVERY EFFICENCY	N/A	N/A	N/A	N/A	0.9	0.9	N/A
97	i	STG 2 HYDRAULIC COUPLING EFFICIENCY	N/A	N/A	N/A	N/A	0.965	0.965	N/A
98	i	STAGE 2 HIGH HD PUMP PRESS RISE, BAR	N/A	N/A	N/A	N/A	0	0	N/A
99	i	STAGE 2 HIGH HEAD PUMP EFFICIENCY	N/A	N/A	N/A	N/A	0.9	0.9	N/A
100	i	OTHER SPECIFIC POWER USE, kWe/CU.M/D	N/A	N/A	N/A	N/A	0.0408	0.0408	N/A
101	i	RO PLANT AVAILABILITY	N/A	N/A	N/A	N/A	0.91	0.91	N/A
102									
103		COST INPUT DATA							
104									
105		POWER PLANT COST DATA:							
106	i	SPEC. CONSTR. COST, $/kWe ($/kWt)	713	1439	1266	400	1000	1000	1714
107		ADDITIONL CONSTR. COST, $/kWe ($/kWt)	71	144	127	40	100	100	171
108		TOTAL CONSTR. COST, $/kWe ($/kWt)	784	1583	1393	440	1100	1100	1885
109	i	CONSTRUCTION LEAD TIME, MONTHS	36	36	36	18	18	18	18
110	i	SPECIFIC O&M COST, $/MWeh ($/MWth)	3.63	3.63	4.18	13.20	7.70	7.70	2.53
111	i	GAS PRICE AT STARTUP, $/BOE	N/A	N/A	N/A	15.50	15.50	15.50	N/A
112	i	SPECIFIC FUEL COST, $/MWeh ($/MWth)	7.57	3.95	3.91	9.41	20.46	20.46	0
113		LEVELIZED ANNUAL DECOMM. COST, M$	0.16	0.12	0.09	0.00	0.00	0.00	0.00
114	i	FUEL ANNUAL REAL ESCALATION, %	0	0	0	2	2	2	0
115									
116		THERMAL WATER PLANT COST DATA:							
117	i	CORRECTION FACTOR FOR UNIT SIZE	0.9	0.9	0.9	0.9	N/A	N/A	0.9
118	i	*BASE UNIT COST, $/CU.M/D*	*1680*	*1680*	*1680*	*1680*	*N/A*	*N/A*	*1500*
119		INTERMEDIATE LOOP UNIT COST, $/CU.M/D	104	79	61	0	N/A	N/A	0
120	i	WATER PLT COST CONTG'CY FACTOR	0.10	0.10	0.10	0.10	N/A	N/A	0.10
121	i	WATER PLT OWNERS COST FACTOR	0.05	0.05	0.05	0.05	N/A	N/A	0.05
122	i	WATER PLT LEAD TIME,MONTHS	12	12	24	24	N/A	N/A	24
123	i	AVERAGE MANAGEMENT SALARY, $/YR	66000	66000	66000	66000	N/A	N/A	66000
124	i	AVERAGE LABOR SALARY, $/YR	29700	29700	29700	29700	N/A	N/A	29700
125	i	SPECIFIC O&M SPARE PARTS COST, $/CU.M	0.04	0.04	0.04	0.04	N/A	N/A	0.04
126	i	SPECIFIC O&M CHEM COST, $/CU.M	0.02	0.02	0.02	0.02	N/A	N/A	0.02
127	i	WATER PLT O&M INS COST,% BASE CAP	0.50	0.50	0.50	0.50	N/A	N/A	0.50
128	i	BACKUP HEAT SOURCE UNIT COST, $/MWt	50000	50000	50000	50000	N/A	N/A	50000
129									
130		RO OR MED/VC WATER PLANT COST DATA:							
131	i	*BASE UNIT COST, $/CU.M/D*	*N/A*	*N/A*	*N/A*	*N/A*	*1125*	*1650*	*N/A*
132	i	WATER PLT COST CONTG'CY FACTOR	N/A	N/A	N/A	N/A	0.10	0.10	N/A
133	i	WATER PLT OWNERS COST FACTOR	N/A	N/A	N/A	N/A	0.05	0.05	N/A
134	i	WATER PLT LEAD TIME,MONTHS	N/A	N/A	N/A	N/A	12	12	N/A
135	i	AVERAGE MANAGEMENT SALARY, $/YR	N/A	N/A	N/A	N/A	66000	66000	N/A
136	i	AVERAGE LABOR SALARY, $/YR	N/A	N/A	N/A	N/A	29700	29700	N/A
137	i	O&M MEMBRANE REPLACEMENT COST, $/CU.M	N/A	N/A	N/A	N/A	0.12	0.12	N/A
138	i	O&M SPARE PARTS COST, $/CU.M	N/A	N/A	N/A	N/A	0.03	0.03	N/A
139	i	SPECIFIC CHEMICAL COST, $/CU.M	N/A	N/A	N/A	N/A	0.07	0.07	N/A
140	i	WATER PLT O&M INS COST,% BASE CAP	N/A	N/A	N/A	N/A	0.50	0.50	N/A
141									
142		ECONOMIC PARAMETERS INPUT DATA							
143									
144		CASE 1: 5% INTEREST RATE							
145	i	AFUDC RATE, %/YR	5.00	5.00	5.00	5.00	5.00	5.00	5.00

	A	B	C	D	E	F	G	H	I
146		LN-94$ FIXED CHARGE RATE, %	6.51	6.51	6.51	6.51	6.51	6 51	6 51
147	i	PURCHASED ELECTRICITY COST, $/kWh	0.04	0.04	0 04	0.04	N/A	N/A	0 04
148									
149		CASE 2: 8% INTEREST RATE							
150	i	AFUDC RATE, %/YR	8.00	8.00	8 00	8 00	8.00	8 00	8 00
151		LN-94$ FIXED CHARGE RATE, %	8.88	8.88	8 88	8 88	8.88	8 88	8 88
152	i	PURCHASED ELECTRICITY COST, $/kWh	0 05	0 05	0 05	0 05	N/A	N/A	0 05
153									
154		CASE 3: 10% INTEREST RATE							
155	i	AFUDC RATE, %/YR	10.00	10 00	10 00	10 00	10 00	10 00	10 00
156		LN-94$ FIXED CHARGE RATE, %	10 61	10 61	10 61	10 61	10 61	10 61	10 61
157	i	PURCHASED ELECTRICITY COST, $/kWh	0 06	0 06	0 06	0 06	N/A	N/A	0 06
158									
159		PERFORMANCE CALCULATIONS							
160									
161		SINGLE-PURPOSE PLT PERFORMANCE:							
162		THERMAL POWER, MWt	60.00	46.00	36 00	36 00	54.35	54 35	50 00
163		PLANT GROSS OUTPUT, MWe	N/A	N/A	N/A	N/A	26.32	26.32	N/A
164		PLANT AUX LOADS, MWe	0.60	0.46	0.36	0 36	1.32	1 32	0 00
165		CONDENSER COOLING WTR FLOW, kg/s	N/A	N/A	N/A	N/A	N/A	N/A	N/A
166		CONDENSER COOLING WTR PUMP POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A
167		REJECT HEAT LOAD, MWt	N/A	N/A	N/A	N/A	N/A	N/A	N/A
168		TURBINE EXHAUST FLOW, kg/s	N/A	N/A	N/A	N/A	N/A	N/A	N/A
169		OPERATING AVAILABILITY	0 903	0 903	0 903	0 903	0.903	0.903	0 903
170									
171		DUAL-PURPOSE POWER PLANT PERFORMANCE:							
172		LOST SHAFTWORK, MWs	N/A	N/A	N/A	N/A	N/A	N/A	N/A
173		LOST ELECTRICITY PRODUCTION, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A
174		NET ELECTRICITY PRODUCED, MWe	N/A	N/A	N/A	N/A	25.00	25 00	N/A
175		TOTAL HEAT TO WTR PLT, MWt	60	46	36	36	N/A	N/A	50
176		BACKPRESSURE TURB. EXHAUST FLOW, kg/s	N/A	N/A	N/A	N/A	N/A	N/A	N/A
177		INTERMEDIATE LOOP FLOW RATE, kg/s	7177	5502	4306	N/A	N/A	N/A	N/A
178		INTERMEDIATE LOOP PUMPING POWER, MWe	1.26	0.97	0.76	N/A	N/A	N/A	N/A
179		FLASH STEAM FLOW TO MED, kg/s	25.9	19.8	15.5	15.5	N/A	N/A	21 6
180									
181		THERMAL WATER PLANT PERFORMANCE:							
182		MAXIMUM WATER PLT CAPACITY, CU.M/DAY	23,525	23,928	24,034	24,034	N/A	N/A	24,128
183		NUMBER OF UNITS	12	4	3	3	N/A	N/A	3
184		SEAWATER FLOW, kg/s	2,677	2,052	1,606	1,606	N/A	N/A	2,231
185		INCREMENTAL SEAWATER PUMPING PWR, MWe	0.53	0.41	0 32	0 32	N/A	N/A	0 44
186		WATER PLANT INTERNAL POWER USE, MWe	1.95	1 99	1 99	1 99	N/A	N/A	2 00
187		WTR PLT+INT.LOOP+SEAWTR PUMP PWR, MWe	3.75	3 36	3 07	2 32	N/A	N/A	2 45
188		WTR PLT OPERATING AVAILABILITY	0.907	0.907	0 907	0 907	N/A	N/A	0 907
189		COMBINED HEAT SOURCE AVAILABILITY	0.99	0.99	0 99	0 99	N/A	N/A	0 99
190		COMBINED PWR/WTR PLT CAPACITY FACTOR	0.898	0.898	0 898	0.898	N/A	N/A	0 898
191		ANNUAL WATER PRODUCTION, CU.M/YR	7,711,582	7,843,822	7,878,616	7,878,616	N/A	N/A	7,909,240
192		AVRG DAILY WATER PRODUCTION, CU.M/D	21,128	21,490	21,585	21,585	N/A	N/A	21,669
193									
194		RO OR MED/VC WATER PLANT PERFORMANCE:							
195		PRODUCTION CAPACITY, CU M/DAY	N/A	N/A	N/A	N/A	24,000	24 000	N/A

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	A	B	C	D	E	F	G	H	I
196		NUMBER OF RO UNITS	N/A	N/A	N/A	N/A	2	2	N/A
197		SEAWATER FLOW, kg/s	N/A	N/A	N/A	N/A	555 56	555 56	N/A
198		STAND-ALONE SEAWATER PUMPING PWR, MWe	N/A	N/A	N/A	N/A	0 11	0 11	N/A
199		CONTIGUOUS SEAWATER PUMPING PWR, MWe	N/A	N/A	N/A	N/A	0 00	0 00	N/A
200		BOOSTER PUMP POWER, MWe	N/A	N/A	N/A	N/A	0 22	0 22	N/A
201		STAGE 1 HIGH HEAD PUMP POWER, MWe	N/A	N/A	N/A	N/A	5 86	9 12	N/A
202		ENERGY RECOVERY, MWe	N/A	N/A	N/A	N/A	2 08	3 04	N/A
203		STAGE 2 HIGH HEAD PUMP POWER, MWe	N/A	N/A	N/A	N/A	0 00	0 00	N/A
204		OTHER POWER, MWe	N/A	N/A	N/A	N/A	0 98	0 98	N/A
205		TOTAL STAND-ALONE POWER USE, MWe	N/A	N/A	N/A	N/A	5 09	7 38	N/A
206		TOTAL CONTIGUOUS POWER USE, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A
207		ANNUAL AVG WATER PRODUCTION, CU M/YR	N/A	N/A	N/A	N/A	7,971,600	7 971 600	N/A
208		AVG DAILY WATER PRODUCTION, CU M/DAY	N/A	N/A	N/A	N/A	21,840	21,840	N/A
209		SPEC (S-A) PWR CONSUMPTION, kWh/CU M	N/A	N/A	N/A	N/A	5 09	7 38	N/A
210		SPEC (CONT) PWR CONSUMPTION, kWh/CU M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
211		NET PWR PLNT SALEABLE PWR (S-A), MWe	N/A	N/A	N/A	N/A	19 91	17 62	N/A
212		NET PWR PLNT SALEABLE PWR (CONT), MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A
213									
214		COST CALCULATIONS							
215									
216		THERMAL WATER PLANT COSTS.							
217		NUMBER OF UNITS	12	4	3	3	N/A	N/A	3
218		CORRECTION FACTOR FOR NO OF UNITS	0 763	0 935	0 959	0 959	N/A	N/A	0 959
219		WATER PLT SPECIFIC BASE COST,$/CU M/D	1153	1413	1450	1450	N/A	N/A	1294
220		INC IN/OUTFALL SPEC BS CT, $/CU M/D	537	450	387	387	N/A	N/A	469
221		INTERMEDIATE LOOP COST, $/CU M/D	104	79	61	0	N/A	N/A	0
222		TOTAL SPECIFIC BASE COST, $/CU M/D	1794	1942	1898	1836	N/A	N/A	1763
223		NUMBER OF MANAGEMENT PERSONNEL	5	5	5	5	N/A	N/A	5
224		WATER PLT O&M MGMT COST,M$/Y	0 33	0 33	0 33	0 33	N/A	N/A	0 33
225		NUMBER OF LABOR PERSONNEL	18	18	18	18	N/A	N/A	18
226		WATER PLT O&M LABOR COST,M$/Y	0 54	0 55	0 55	0 55	N/A	N/A	0 55
227		WATER PLT ADJUSTED BASE COST,M$	42 21	46 46	45 61	44 13	N/A	N/A	42 54
228		BACKUP HEAT SOURCE BASE COST, M$	3 00	2 30	1 80	1 80	N/A	N/A	2 50
229		TOTAL WATER PLANT BASE COST, M$	45 21	48 76	47 41	45 93	N/A	N/A	45 04
230		WATER PLT OWNERS COST,M$	2 26	2 44	2 37	2 30	N/A	N/A	2 25
231		WATER PLT CONTINGENCY ,M$	4 75	5 12	4 98	4 82	N/A	N/A	4 73
232		WATER PLT TOT CONSTRUCTION COST M$	52 22	56 32	54 76	53 05	N/A	N/A	52 03
233		WATER PLT O&M COST M$/YR	1 55	1 58	1 58	1 57	N/A	N/A	1 56
234									
235		RO OR MED/VC WATER PLANT COSTS							
236		NUMBER OF UNITS	N/A	N/A	N/A	N/A	2	2	N/A
237		CORRECTION FACTOR FOR NO OF UNITS	N/A	N/A	N/A	N/A	0 983	0 983	N/A
238		PROCESS PLT SPECIFIC COST,$/CU M/D	N/A	N/A	N/A	N/A	1106	1623	N/A
239		STND-ALN IN/OUTFALL SPEC CT, $/CU M/D	N/A	N/A	N/A	N/A	205	205	N/A
240		STND-ALN WTR PLNT SPEC CT, $/CU M/D	N/A	N/A	N/A	N/A	1311	1827	N/A
241		NUMBER OF MANAGEMENT PERSONNEL	N/A	N/A	N/A	N/A	5	5	N/A
242		O&M MGMT COST,M$/Y	N/A	N/A	N/A	N/A	0 33	0 33	N/A
243		NUMBER OF LABOR PERSONNEL	N/A	N/A	N/A	N/A	18	18	N/A
244		O&M LABOR COST,M$/Y	N/A	N/A	N/A	N/A	0 55	0 55	N/A
245		STND-ALN WTR PLT ADJUSTED BASE CT M$	N/A	N/A	N/A	N/A	31 47	43 86	N/A

	A	B	C	D	E	F	G	H	I
246		CONTIGUOUS WTR PLT ADJUSTED BS CT,M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A
247		WATER PLT OWNERS COST,M$	N/A	N/A	N/A	N/A	1.57	2.19	N/A
248		WATER PLT CONTINGENCY ,M$	N/A	N/A	N/A	N/A	3.30	4.61	N/A
249		STND-ALN WTR PLT TOT CONSTRUCT CT, M$	N/A	N/A	N/A	N/A	36.35	50.66	N/A
250		CONTIGUOUS WTR PLT TOT CONSTR CT, M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A
251		WATER PLT O&M COST,M$/YR	N/A	N/A	N/A	N/A	2.79	2.85	N/A
252									
253		ECONOMIC EVALUATIONS							
254									
255		CASE 1: 6% INTEREST RATE							
256		-POWER PLANT COST							
257		TOTAL CONSTRUCTION COST, M$	47.06	72.81	50.13	15.84	27.50	27.50	94.27
258		AFUDC, M$	3.57	5.53	3.81	0.59	1.02	1.02	3.51
259		TOTAL PLANT INVESTMENT, M$	50.63	78.34	53.94	16.43	28.52	28.52	97.78
260		LEVELIZED ANNUAL CAPITAL COST, M$	3.29	5.10	3.51	1.07	1.86	1.86	6.36
261		FUEL LEVELIZED FACTOR	1.00	1.00	1.00	1.60	1.60	1.60	1.00
262		ANNUAL FUEL COST, M$	3.59	1.44	1.11	4.28	6.46	6.46	0.00
263		ANNUAL O&M COST, M$	1.72	1.32	1.19	3.76	1.52	1.52	1.00
264		ELEC. PWR COST (HEAT ONLY), M$/YR	0.19	0.15	0.11	0.11	N/A	N/A	0.00
265		DECOMMISSIONING COST, M$	0.16	0.12	0.09	0.00	0.00	0.00	0.00
266		TOTAL ANNUAL REQUIRED REVENUE, M$	8.95	8.12	6.02	9.22	9.84	9.84	7.36
267		ANNUAL ELECTRICITY PRODUCTION, KWH	N/A	N/A	N/A	N/A	197,647,500	197,647,500	N/A
268		LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	N/A	0.050	0.050	N/A
269									
270		-THERMAL (MED) PLANT:							
271		ANNUAL WATER PROD, CU.M/YR	7,711,582	7,843,822	7,878,616	7,878,616	N/A	N/A	7,909,240
272		TOTAL CONSTRUCTION COST, M$	52.22	56.32	54.76	53.05	N/A	N/A	52.03
273		AFUDC ,M$	1.29	1.39	2.74	2.65	N/A	N/A	2.60
274		TOTAL INVESTMENT ,M$	53.51	57.71	57.49	55.70	N/A	N/A	54.63
275		WATER CT, FIXED CHARGE, M$/YR	3.48	3.75	3.74	3.62	N/A	N/A	3.55
276		WATER CT, HEAT CHARGE, M$/YR	8.95	8.12	6.02	9.22	N/A	N/A	7.36
277		WATER CT, ELEC CHARGE, M$/YR	1.18	1.06	0.97	0.73	N/A	N/A	0.77
278		WATER CT, O&M CHARGE, M$/YR	1.55	1.58	1.58	1.57	N/A	N/A	1.56
279		TOTAL WATER COST, $/CU.M	1.97	1.85	1.56	1.92	N/A	N/A	1.68
280									
281		-STAND-ALONE RO PLANT:							
282		SPECIFIED OUTPUT							
283		ANNUAL WATER PROD, CU.M/YR	N/A	N/A	N/A	N/A	7,971,600	7,971,600	N/A
284		TOTAL CONSTRUCTION COST ,M$	N/A	N/A	N/A	N/A	36.35	50.66	N/A
285		AFUDC ,M$	N/A	N/A	N/A	N/A	0.90	1.25	N/A
286		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	N/A	37.24	51.91	N/A
287		WATER CT, FIXED CHARGE, M$/YR	N/A	N/A	N/A	N/A	2.42	3.38	N/A
288		WATER CT, ELEC CHARGE, M$/YR	N/A	N/A	N/A	N/A	2.02	2.93	N/A
289		WATER CT, O&M CHARGE, M$/YR	N/A	N/A	N/A	N/A	2.79	2.85	N/A
290		TOTAL WATER COST, $/CU.M	N/A	N/A	N/A	N/A	0.91	1.15	N/A
291		-CONTIGUOUS RO PLANT:							
292		ANNUAL WATER PROD, CU.M/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
293		TOTAL CONSTRUCTION COST ,M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A
294		AFUDC ,M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A
295		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	A	B	C	D	E	F	G	H	I
296		WATER CT, FIXED CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
297		WATER CT, ELEC CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
298		WATER CT, O&M CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
299		TOTAL WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
300									
301		HYBRID MED/RO							
302		HYBRID ANNUAL WATER PRODUCTION	N/A	N/A	N/A	N/A	N/A	N/A	N/A
303		COMBINED WTR COST FOR HYBRID, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
304									
305		CASE 2: 8% INTEREST RATE							
306		-POWER PLANT COST							
307		TOTAL CONSTRUCTION COST, M$	47.06	72.81	50.13	15.84	27.50	27.50	94.27
308		AFUDC, M$	5.76	8.91	6.13	0.94	1.63	1.63	5.60
309		TOTAL PLANT INVESTMENT, M$	52.82	81.72	56.27	16.78	29.13	29.13	99.87
310		LEVELIZED ANNUAL CAPITAL COST, M$	4.69	7.26	5.00	1.49	2.59	2.59	8.87
311		FUEL LEVELIZED FACTOR	1.00	1.00	1.00	1.54	1.54	1.54	1.00
312		ANNUAL FUEL COST, M$	3.59	1.44	1.11	4.12	6.23	6.23	0.00
313		ANNUAL O&M COST, M$	1.72	1.32	1.19	3.76	1.52	1.52	1.00
314		DECOMMISSIONING COST, M$	0.16	0.12	0.09	0.00	0.00	0.00	0.00
315		ELEC. PWR COST (HEAT ONLY), M$/YR	0.24	0.18	0.14	0.14	N/A	N/A	0.00
316		TOTAL ANNUAL REQUIRED REVENUE, M$	10.40	10.32	7.54	9.51	10.33	10.33	9.87
317		ANNUAL ELECTRICITY PRODUCTION, KWH	N/A	N/A	N/A	N/A	197,647,500	197,647,500	N/A
318		LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	N/A	0.052	0.052	N/A
319									
320		-THERMAL (MED) PLANT:							
321		TOTAL CONSTRUCTION COST, M$	52.22	56.32	54.76	53.05	N/A	N/A	52.03
322		AFUDC, M$	2.05	2.21	4.38	4.24	N/A	N/A	4.16
323		TOTAL WATER PLANT INVESTMENT, M$	54.27	58.53	59.14	57.30	N/A	N/A	56.19
324		WATER CT, FIXED CHARGE, M$/YR	4.82	5.20	5.25	5.09	N/A	N/A	4.99
325		WATER CT, HEAT CHARGE, M$/YR	10.40	10.32	7.54	9.51	N/A	N/A	9.87
326		WATER CT, ELEC CHARGE, M$/YR	1.47	1.32	1.21	0.91	N/A	N/A	0.96
327		WATER CT, O&M CHARGE, M$/YR	1.55	1.58	1.58	1.57	N/A	N/A	1.56
328		TOTAL WATER COST, $/CU.M	2.37	2.35	1.98	2.17	N/A	N/A	2.20
329									
330		-STAND-ALONE RO PLANT:							
331		TOTAL CONSTRUCTION COST ,M$	N/A	N/A	N/A	N/A	36.35	50.66	N/A
332		AFUDC ,M$	N/A	N/A	N/A	N/A	1.43	1.99	N/A
333		-TOTAL INVESTMENT ,M$	N/A	N/A	N/A	N/A	37.77	52.64	N/A
334		WATER CT, FIXED CHARGE, M$/YR	N/A	N/A	N/A	N/A	3.36	4.68	N/A
335		WATER CT, ELEC CHARGE, M$/YR	N/A	N/A	N/A	N/A	2.12	3.08	N/A
336		WATER CT, O&M CHARGE, M$/YR	N/A	N/A	N/A	N/A	2.79	2.85	N/A
337		TOTAL WATER COST, $/CU.M	N/A	N/A	N/A	N/A	1.04	1.33	N/A
338		-CONTIGUOUS RO PLANT:							
339		TOTAL CONSTRUCTION COST ,M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A
340		AFUDC ,M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A
341		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A
342		WATER CT, FIXED CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
343		WATER CT, ELEC CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
344		WATER CT, O&M CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
345		TOTAL WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	A	B	C	D	E	F	G	H	I
346									
347		HYBRID MED/RO							
348		HYBRID ANNUAL WATER PRODUCTION	N/A	N/A	N/A	N/A	N/A	N/A	N/A
349		COMBINED WTR COST FOR HYBRID, $/CU M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
350									
351		CASE 3: 10% INTEREST RATE							
352		-POWER PLANT COST							
353		TOTAL CONSTRUCTION COST, M$	47.06	72.81	50.13	15.84	27.50	27.50	94.27
354		AFUDC, M$	7.23	11.19	7.71	1.17	2.04	2.04	6.99
355		TOTAL PLANT INVESTMENT, M$	54.29	84.00	57.84	17.01	29.54	29.54	101.26
356		LEVELIZED ANNUAL CAPITAL COST, M$	5.76	8.91	6.14	1.80	3.13	3.13	10.74
357		FUEL LEVELIZED FACTOR	1.00	1.00	1.00	1.51	1.51	1.51	1.00
358		ANNUAL FUEL COST, M$	3.59	1.44	1.11	4.04	6.09	6.09	0.00
359		ANNUAL O&M COST, M$	1.72	1.32	1.19	3.76	1.52	1.52	1.00
360		DECOMMISSIONING COST, M$	0.16	0.12	0.09	0.00	0.00	0.00	0.00
361		ELEC. PWR COST (HEAT ONLY), M$/YR	0.28	0.22	0.17	0.17	N/A	N/A	0.00
362		TOTAL ANNUAL REQUIRED REVENUE, M$	11.51	12.01	8.70	9.77	10.75	10.75	11.74
363		ANNUAL ELECTRICITY PRODUCTION, KWH	N/A	N/A	N/A	N/A	197,647,500	197,647,500	N/A
364		LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	N/A	0.054	0.054	N/A
365									
366		-THERMAL (MED) PLANT:							
367		TOTAL CONSTRUCTION COST	52.22	56.32	54.76	53.05	N/A	N/A	52.03
368		AFUDC ,M$	2.55	2.75	5.48	5.31	N/A	N/A	5.20
369		TOTAL INVESTMENT ,M$	54.77	59.07	60.23	58.36	N/A	N/A	57.23
370		WATER CT, FIXED CHARGE, M$/YR	5.81	6.27	6.39	6.19	N/A	N/A	6.07
371		WATER CT, HEAT CHARGE, M$/YR	11.51	12.01	8.70	9.77	N/A	N/A	11.74
372		WATER CT, ELEC CHARGE, M$/YR	1.77	1.59	1.45	1.09	N/A	N/A	1.16
373		WATER CT, O&M CHARGE, M$/YR	1.55	1.58	1.58	1.57	N/A	N/A	1.56
374		TOTAL WATER COST, $/CU M	2.68	2.73	2.30	2.36	N/A	N/A	2.60
375									
376		-STAND-ALONE RO PLANT:							
377		TOTAL CONSTRUCTION COST, M$	N/A	N/A	N/A	N/A	36.35	50.66	N/A
378		AFUDC, M$	N/A	N/A	N/A	N/A	1.77	2.47	N/A
379		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	N/A	38.12	53.13	N/A
380		WATER CT, FIXED CHARGE, M$/YR	N/A	N/A	N/A	N/A	4.04	5.64	N/A
381		WATER CT, ELEC CHARGE, M$/YR	N/A	N/A	N/A	N/A	2.21	3.20	N/A
382		WATER CT, O&M CHARGE, M$/YR	N/A	N/A	N/A	N/A	2.79	2.85	N/A
383		TOTAL WATER COST, $/CU M	N/A	N/A	N/A	N/A	1.13	1.47	N/A
384		-CONTIGUOUS RO PLANT:							
385		TOTAL CONSTRUCTION COST, M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A
386		AFUDC, M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A
387		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A
388		WATER CT, FIXED CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
389		WATER CT, ELEC CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
390		WATER CT, O&M CHARGE, M$/YR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
391		TOTAL WATER COST, $/CU M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
392									
393		HYBRID MED/RO							
394		HYBRID ANNUAL WATER PRODUCTION							
395		COMBINED WTR COST FOR HYBRID, $/CU M	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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	A	B	C	D	E	F	G	H	I
396									
397		SUMMARY							
398									
399		CASE	Morocco-1	Morocco-2	Morocco-3	Morocco-4	Morocco-5	Morocco-6	Morocco-7
400		PLANT TYPE	NUCLEAR	NUCLEAR	NUCLEAR	FOSSIL	FOSSIL	FOSSIL	RENEWABLE
401		PRODUCT	HEAT ONLY	HEAT ONLY	HEAT ONLY	HEAT ONLY	POWER ONLY	POWER ONLY	HEAT ONLY
402		REFERENCE OF FLOW DIAGRAM	V	V	V	IX	XVI	XVII	XX
403		WATER PLANT TYPE	MED	MED	MED	MED	RO	MED/VC	MED
404		REACTOR TYPE	SES-10	GEYSER	TRIGA	GAS BOILER	DIESEL	DIESEL	SOLAR POND
405		SELECTED NET OUTPUT, MWe (MWt)	60	46	36	36	25	25	50
406		PRODUCT DRINKING WATER STANDARD	WHO	WHO	WHO	WHO	WHO	WHO	WHO
407									
408		SUMMARY CASE 1: 6% INT & AFUDC RATE							
409		-LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	N/A	0.050	0.050	N/A
410		-PURCHASED POWER COST, $/kWh	0.04	0.04	0.04	0.04	N/A	N/A	0.04
411		-THERMAL MED PLANT (OPTIMIZED)							
412		WATER PRODUCTION CAPACITY, CU M/D	23525	23928	24034	24034	N/A	N/A	24128
413		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A
414		WATER COST, $/CU.M	1.97	1.85	1.56	1.92	N/A	N/A	1.68
415		-STAND-ALONE RO PLT (MED EQ. OUTPUT)							
416		WATER PRODUCTION CAPACITY, CU.M/D	N/A	N/A	N/A	N/A	24000	24000	N/A
417		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	19.91	17.62	N/A
418		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	0.91	1.15	N/A
419		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)							
420		WATER PRODUCTION CAPACITY, CU M/D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
421		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A
422		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
423		-HYBRID COMBINED MED/RO							
424		WATER PRODUCTION CAPACITY, CU M/D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
425		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A
426		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
427									
428		SUMMARY CASE 2: 8% INT & AFUDC RATE							
429		-LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	N/A	0.052	0.052	N/A
430		-PURCHASED POWER COST, $/kWh	0.05	0.05	0.05	0.05	N/A	N/A	0.05
431		-THERMAL MED PLANT (OPTIMIZED)							
432		WATER PRODUCTION CAPACITY, CU M/D	23525	23928	24034	24034	N/A	N/A	24128
433		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A
434		WATER COST, $/CU.M	2.37	2.35	1.98	2.17	N/A	N/A	2.20
435		-STAND-ALONE RO PLT (MED EQ. OUTPUT)							
436		WATER PRODUCTION CAPACITY, CU M/D	N/A	N/A	N/A	N/A	24000	24000	N/A
437		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	19.91	17.62	N/A
438		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	1.04	1.33	N/A
439		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)							
440		WATER PRODUCTION CAPACITY, CU M/D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
441		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A
442		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
443		-HYBRID COMBINED MED/RO							
444		WATER PRODUCTION CAPACITY, CU M/D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
445		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	A	B	C	D	E	F	G	H	I
446		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
447									
448		SUMMARY CASE 3: 10% INT & AFUDC RATE							
449		-LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	N/A	0.054	0.054	N/A
450		-PURCHASED POWER COST, $/kWh	0.06	0.06	0.06	0.06	N/A	N/A	0 06
451		-THERMAL MED PLANT (OPTIMIZED)							
452		WATER PRODUCTION CAPACITY, CU M/D	23525	23928	24034	24034	N/A	N/A	24128
453		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A
454		WATER COST, $/CU.M	2.68	2.73	2 30	2.36	N/A	N/A	2 60
455		-STAND ALONE RO PLT (MED EQ. OUTPUT)							
456		WATER PRODUCTION CAPACITY, CU.M/D	N/A	N/A	N/A	N/A	24000	24000	N/A
457		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	19.91	17 62	N/A
458		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	1.13	1 47	N/A
459		-CONTIGUOUS RO PLT (MED EQ. OUTPUT)							
460		WATER PRODUCTION CAPACITY, CU.M/D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
461		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A
462		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
463		-HYBRID COMBINED MED/RO							
464		WATER PRODUCTION CAPACITY, CU.M/D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
465		NET SALEABLE POWER, MWe	N/A	N/A	N/A	N/A	N/A	N/A	N/A
466		WATER COST, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
467									
468		INVESTMENT COSTS - 8% INTEREST RATE							
469									
470		POWER PLANT							
471		SPECIFIC CONSTRUCTION COST, $/kW	784	1583	1393	440	1100	1100	1885
472		- POWER PLANT CONSTRUCTION, M$	47	73	50	16	28	28	94
473		- POWER PLANT IDC, M$	6	9	6	1	2	2	6
474		TOTAL INVESTMENT COST, M$	53	82	56	17	29	29	100
475		SPECIFIC INVESTMENT COST, $/kW	880	1777	1563	466	1165	1165	1997
476									
477		POWER & THERMAL MED PLANT							
478		- POWER PLANT CONSTRUCTION, M$	47	73	50	16	28	28	94
479		- POWER PLANT IDC, M$	6	9	6	1	2	2	6
480		-PWR PLT COST PORTION OF WTR PROD M$	53	82	56	17	N/A	N/A	100
481		- MED PLANT CONSTRUCTION, M$	52	56	55	53	N/A	N/A	52
482		- MED PLANT IDC, M$	2	2	4	4	N/A	N/A	4
483		TOTAL INVESTMENT COST, M$	107	140	115	74	N/A	N/A	156
484		- MED CAPACITY, CU.M/D	23525	23928	24034	24034	N/A	N/A	24128
485		SPECIFIC INVESTMENT COST, $/CU.M/D	4552	5862	4802	3082	N/A	N/A	6468
486									
487		POWER & S-A RO (MED EQUIV.) PLANT							
488		- POWER PLANT CONSTRUCTION, M$	N/A	N/A	N/A	N/A	28	28	N/A
489		- POWER PLANT IDC, M$	N/A	N/A	N/A	N/A	2	2	N/A
490		-PWR PLT COST PORTION OF WTR PROD M$	N/A	N/A	N/A	N/A	6	9	N/A
491		- RO PLANT CONSTRUCTION, M$	N/A	N/A	N/A	N/A	36	51	N/A
492		- RO PLANT IDC, M$	N/A	N/A	N/A	N/A	1	2	N/A
493		TOTAL INVESTMENT COST, M$	N/A	N/A	N/A	N/A	44	61	N/A
494		- RO (MED EQUIV.) CAPACITY, CU.M/D	N/A	N/A	N/A	N/A	24000	24000	N/A
495		SPECIFIC INVESTMENT COST, $/CU.M/D	N/A	N/A	N/A	N/A	1821	2552	N/A

	A	B	C	D	E	F	G	H	I
496									
497		COST SUMMARY: 8% INTEREST RATE							
498									
499		-POWER PLANT COST							
500		TOTAL PLANT INVESTMENT, M$	52.82	81.72	56.27	16.78	29.13	29.13	99.87
501		LEVELIZED ANNUAL CAPITAL COST, M$	4.69	7.26	5.00	1.49	2.59	2.59	8.87
502		TOTAL ANNUAL REQUIRED REVENUE, M$	10.40	10.32	7.54	9.51	10.33	10.33	9.87
503		LEVELIZED POWER COST, $/kWh	N/A	N/A	N/A	N/A	0.052	0.052	N/A
504									
505		-THERMAL (MED) PLANT:							
506		TOTAL WATER PLANT INVESTMENT, M$	54.27	58.53	59.14	57.30	N/A	N/A	56.19
507		WATER CT, FIXED CHARGE, $/CU M	0.63	0.66	0.67	0.65	N/A	N/A	0.63
508		WATER CT, ENERGY CHARGE, $/CU M	1.54	1.48	1.11	1.32	N/A	N/A	1.37
509		WATER CT, O&M CHARGE, $/CU M	0.20	0.20	0.20	0.20	N/A	N/A	0.20
510		TOTAL WATER COST, $/CU M	2.37	2.35	1.98	2.17	N/A	N/A	2.20
511									
512		-STAND-ALONE RO PLANT:							
513		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	N/A	37.77	52.64	N/A
514		WATER CT, FIXED CHARGE, $/CU M	N/A	N/A	N/A	N/A	0.42	0.59	N/A
515		WATER CT, ENERGY CHARGE, $/CU M	N/A	N/A	N/A	N/A	0.27	0.39	N/A
516		WATER CT, O&M CHARGE, $/CU M	N/A	N/A	N/A	N/A	0.35	0.36	N/A
517		TOTAL WATER COST, $/CU M	N/A	N/A	N/A	N/A	1.04	1.33	N/A
518									
519		-CONTIGUOUS RO PLANT:							
520		TOTAL INVESTMENT ,M$	N/A	N/A	N/A	N/A	N/A	N/A	N/A
521		WATER CT, FIXED CHARGE, $/CU.M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
522		WATER CT, ENERGY CHARGE, $/CU M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
523		WATER CT, O&M CHARGE, $/CU M	N/A	N/A	N/A	N/A	N/A	N/A	N/A
524		TOTAL WATER COST, $/CU M	N/A	N/A	N/A	N/A	N/A	N/A	N/A

ANNEX VI

NATIONAL PARTICIPATION AREAS

Every country has the overall responsibility for planning and implementation of its national nuclear power programme, including nuclear desalination. These responsibilities cannot be carried out without national participation, which in turn requires national manpower.

The activities involved in nuclear power programmes are listed in Table VI.1. The responsibility for the fundamental decisions on all activities must always remain within the country itself.

There are certain activities for which full responsibility has to be born by national organizations and which should be primarily executed by national manpower, whatever the contracting agreements. These are considered "essential" activities for national participation and are indicated in Table VI.1. Expert help from abroad could be obtained and used up to a point, but only for technical assistance and not as a complete replacement of the national effort [63].

Table VI.2 contains a representative list of items of equipment and components for nuclear power plants. The index numbers correspond to an assessment of the technical difficulty in fabrication (including achievement of quality requirements) and relative costs.

Some materials needed for a nuclear power project do not differ from those required for conventional projects, but there are others which involve a certain additional degree of complexity for their provision by national sources. Table VI.3 lists some of these materials (except fuel) and indicates the degree of complexity for their supply using an index number that combines technical difficulty, relative amounts needed and relative cost. The complexity related to cement production and structural, as well as, standard steels is mainly due to the large amounts required, while the complexity for special steels, Zircaloy or heavy water production is mainly related to technological difficulties involved.

TABLE VI.1: NUCLEAR POWER PROGRAMME ACTIVITIES

No.	Activity	National participation considered essential [a]	Technical difficulty [b]	Manpower effort [b]
1	Nuclear power programme planning and co-ordination	yes	3	1
2	Power system planning	yes	2	1
3	Development of legal and organizational framework	yes	1-2	1
4	International agreements and arrangements	yes	1-2	1
5	National participation planning and co-ordination	yes	2	1
6	Manpower development planning and implementation	yes	2-3	2-3
7	Feasibility studies	yes	3	2
8	Site evaluation	yes	2-3	1-2
9	Preparation of bid specifications	yes	2-3	1-2
10	Bid evaluation	yes	3	2
11	Contracting	yes	3	1
12	Project management (utility)	yes	3	1-2
13	Project management (main contractor)	no	3	2
14	Plant conceptual design	no	3-4	2
15	Basic design engineering	no	3-4	3
16	Detailed design engineering	no	2-3	4
17	Preparation and review of equipment and plant	no	3-4	2
18	specifications	yes	2-3	1
19	Establishment of quality assurance policy	no	2-3	2
20	Quality control and quality assurance implementation	no	1-2	1-2
21	Procurement	no	3	2
22	Safety analysis reporting	yes	2	1
23	Emergency planning	yes	1-2	1
24	Public information and public relations	yes	1	2
25	Safeguards and physical protection	no	1-4	1-4
26	Equipment manufacturing	no	2-3	2
27	Construction management	yes	1	2-3
28	Site preparation	yes	2	4
29	Erection of plant buildings and structures	yes	2-3	3
30	Plant equipment and systems installation	no	2-3	2
31	Plant systems and component testing	no	3-4	1-2
32	Criticality and plant acceptance testing	yes	3-4	3
33	Plant operation and maintenance	yes	1-2	1
34	Radiological protection and environmental surveillance	yes	2	1
35	Fuel procurement	no	1-2	3-4
36	Uranium exploration, mining and milling	no	1-2	1-2
37	Conversion	no	4	3
38	Enrichment	no	3	2
39	Fuel fabrication	yes	2-3	1
40	Fuel management and storage at the power plant	yes	1-2	1
41	Fuel transport and off-site storage within the country	no	4	3
42	Spent fuel reprocessing	yes	2-3	2
43	Waste management	yes	3-4	2-3
44	Nuclear licensing and regulation	no	3-4	3
	Research and development in nuclear power			

[a] For definition see Section

[b] Index number : 1 = low; 2 = medium; 3 = high; 4 = very high

TABLE VI.2: NUCLEAR POWER PLANT EQUIPMENT AND COMPONENTS

No	Component	Technical difficulty [a]	Relative cost [a]
	Nuclear steam supply system (NSSS) and Class 1 equipment		
1	Reactor containment	2-3	3
2	Pressure vessel and internals of calendria	4	4
3	Steam generators	3-4	4
4	Pressurizer	3-4	2
5	Primary pumps	3-4	3
6	Primary piping and valves	3	3
7	Hangers and supports	2	2
8	Spent fuel racks	2	2
9	Spent fuel racks	3	2
10	Air locks and penetrations	2	2
11	Waste treatment systems and components	2	2
12	HEPA air filters	3	1
13	Fuel loading machines (for PHWR)	4	3
14	Control rods and control rod drives	4	3
	Turbine, generator and condenser		
15	Steam turbine	4	4
16	Generator	3	3-4
17	Main condenser	2-3	2-3
18	Secondary piping and valves	2	2
	Balance of Plant (BOP)		
19	Heat exchangers, piping, pumps and valves	2-3	2-3
20	Tanks	1-2	2
21	Heating, ventilation and air conditioning	1-2	2
22	Demineralizer system	2	2
23	Cranes	2-3	1-2
	Electrical		
24	Main transformers	2-3	3
25	Cables	1-2	1-2
26	Switchgear	2	1-2
27	Miscellaneous motors	1-2	1-2
28	Lightning and installation	1	1
29	Auxiliary power supplies and diesel generators	2-3	2-3
	Control and instrumentation		
30	Control room instrumentation	3	3
31	In-core instrumentation	4	2
32	On-line computer	3-4	2
33	Radiation monitoring equipment	2	2
34	Other instrumentation	1-2	1-2

[a] Index number: 1 = low; 2 = medium; 3 = high; 4 = very high

TABLE VI.3: MATERIALS FOR NUCLEAR POWER PROJECTS

Materials	Complexity of supply [a]
Cement	2-3
Structural and standard steel	2-3
Special steel	3-4
Zircaloy	4
Heavy water (for PHWR)	3-4
Copper and aluminum	2
Other special materials	2-4

(a) Index number shows complexity of supply, combining technical difficulty, relative amounts needed and relative costs.

1 = low; 2 = medium; 3 = high; 4 = very high.

ANNEX VII

SURVEY OF REGIONAL MANPOWER AND ENGINEERING CAPABILITIES

The purpose of an assessment of Regional manpower resources is to identify the regional labor pool which can supply the manpower for the nuclear power programme.

The available data on the number of students in the different educational categories (Table VII.1), and the expected future work force out of the educational system, indicate that the present unbalanced pattern of the work force in NACs will continue in the near future.

Generally, the standard of education in high schools, technical institutes, and universities in NACs is high. There is already a pool of engineers available for nuclear power programme activities. Tables VII.2 and VII.3 show the distribution of engineers by discipline and years of experience in the Region.

No problems are foreseen in providing an adequate skilled labor force for construction of NDP or NPP provided that a high level of regional co-operation is maintained, and that suppliers ensure that key supervisory personnel are available.

The general quality and quantity of professional training in the universities and specialized training centers is adequate, although additional training related to the special requirements of a nuclear power programme will be necessary.

There are more than twenty engineering faculties and graduate engineers of different disciplines in NACs. Most of the engineering faculties are parts of universities except the engineering schools in Algeria, Morocco, and Tunisia.

Table VII.4 lists the number of students and teaching staff in some engineering faculties and schools in the Region. The available engineering departments in the North African universities are shown in Table VII.5. It should be remembered, however, that some of the engineering disciplines indicated in Table VII.5 are studied in other departments. For example, irrigation and drainage are studied within civil engineering departments in the Egyptian Universities.

VII.1 ENGINEERING, CONSTRUCTION AND ERECTION CAPABILITIES

There are many consulting firms in the Region that provide basic engineering and other services such as: project management and non-destructive testing. These capabilities in various NACs are discussed below.

VII.1.1 Capabilities In Algeria

Not Available

VII.1.2 Capabilities In Egypt

There are more than 100 consulting companies, in Egypt, that are active in all fields of engineering including desalination. Many of these firms have overseas experience particularly in the oil-rich Gulf States. This is particularly relevant for consultants in the field of desalination.

There are numerous contractors involved in design and construction of dams, tunnels, bridges, factories, power plants, pumping stations and housing. The largest civil engineering emptiness in Egypt that have experience in carrying out large projects all over the Arab World including NAR are the following nationalized companies:

- Arab Contractors (Osman Ahmed Osman).
- Misr Concrete Development Company.
- Nasr General Contracting Company (Hassan Allam).
- Egyptian Contracting Company (Mokhtar Ibrahim).

The Egyptian Government also owns several companies operating in the field of erection of mechanical and electrical equipment, the largest of which are:

- Engineering General Company (EGC).
- Erection and Industrial Services Company (ERISCOM).
- Misr Company For Mechanical and Electrical Projects (KAHROMICA).
- The General Company for Electrical Projects (ELEJECT)
- High Dam Electrical And Industrial Projects Company (HIDELCO).

The last three of the above companies operate within the electricity sector.

VII.1.3 Capabilities In Libya

There are several Libyan contracting companies with good experience in civil, mechanical and electrical construction and erection works. The most important of these are:

- Construction and Metal Work Company (CMWCO), mechanical.
- Electric Construction Company (ECCO), electro-mechanical.
- Arab Union Company, civil.
- African Company for Engineering, civil and electro-mechanical.

VII.1.4 Capabilities In Morocco

There are a number of consulting and engineering firms in Morocco. Some of these have strong ties with similar firms abroad. These firms provide services such as project management and non-destructive testing in the various engineering fields (civil, siting, electro-mechanical, thermal power stations, etc.). There are also a number of contracting firms engaged in the civil, mechanical and electrical construction and erection, particularly in the fields of constructing dams and installations of factories.

VII.1.5 Capabilities In Tunisia

In Tunisia [39], the industrial, scientific and educational infrastructure allows relatively high degrees of national participation in the construction of power plants. The Tunisian Utility of Electricity and Gas (STEG), signs separate contracts with several suppliers providing electro-mechanical fittings, civil works, construction, architect engineering, and non-destructive testing. For each power plant project STEG delegates a local field management team to ensure:

- Co-ordination of construction and testing.
- Quantity surveying of civil works.
- Quality assurance.

Testing and commissioning are carried out in close co-operation between STEG and vendors, under STEG management. Such a contractual approach was found to be suitable in view of the Tunisian national participation goals [39]. For the 2x150 MW Rades-A thermal power plant built in 1985, local participation amounted to 35% of the total construction costs.

TABLE VII.1: NUMBER OF STUDENTS IN THE NORTH AFRICAN COUNTRIES (1986)

Country	Number of students (thousands)				
	Level I	Level II	Level III	Tech. I	Tech. II
Algeria	3635	1999	155	98	14
Egypt	6214	3827	900	877	98
Libya	789	341	45	28	3
Morocco	2228	1281	167	16	27
Tunisia	1327	459	41	79	5
Total	14193	7907	1308	1098	147
%	57.6	32.0	5.3	4.6	0.6

Level I = Primary School, six years
Level II = Preparatory and Secondary Schools, total six
Level III = Universities and Higher Institutes, minimum four years
Tech. I = Technical Secondary Schools
Tech. II = Technical Institutes, two years after secondary school

TABLE VII.2: DISTRIBUTION OF ENGINEERS BY DISCIPLINE IN THE NORTH AFRICAN COUNTRIES

Country	Discipline						Total	Year
	Civil	Arch.	Elect.	Mech.	Chem	Others		
Algeria	1072	172	101	56	897	-	2298	1985
Egypt	2621	18615	43981	52115	9488	3337	170157	1988
Libya	736	362	544	425	619	170	2856	1987
Morocco	349	327	126	49	264	-	1115	1984
Tunisia	622	187	347	94	310	465	2025	1985
Total	45400	19663	45099	52739	11578	3972	178451	
%	25.4	11.0	25.3	29.6	6.5	2.2	100	

*Source Reference [64]

TABLE VII.3: DISTRIBUTION OF ENGINEERS BY YEARS OF EXPERIENCE IN THE NORTH AFRICAN COUNTRIES

Country	Years of Experience			Total	Year
	0 - 5	5 - 10	> 10		
Algeria	1244	670	384	2298	1985
Egypt	37626	27420	155111	170157	1988
Libya	837	1177	842	2856	1987
Morocco	532	359	224	1115	1984
Tunisia	1381	561	83	2025	1985
Total	41620	30187	106644	178451	
%	23.3	16.9	59.8	100	

* Source Reference [64]

TABLE VII.4: FACULTIES OF ENGINEERING IN THE NORTH AFRICAN COUNTRIES

Institution	Students	Teaching Staff	Students per Staff	Year
1 - Algeria				
National School of Engineers, Algiers	887	81	10	1985
National Electrical Institute, Algiers	352	60	6	1985
2 - Egypt				
Cairo University	6731	296	23	1985
Alexandria University	8557	289	30	1985
Ain Shams University, Cairo	6700	290	23	1985
Asyut University	2474	101	24	1985
Mansoura University	1913	121	16	1985
Tanta University	2300	96	24	1985
Zagazig University	746	59	13	1985
Helwan Technological University, Cairo	581	52	11	1985
Menya University	1330	35	38	1985
Munufia University	1811	29	62	1985
Suez Canal University	1800	75	24	1985
Urban Planning Institute (Cairo Univ.)	315	5	63	1985
3 - Libya				
Al-Fateh University, Tripoli	1076	158	7	1987
Qar Yunis University, Benghazi	2042	54	38	1987
4 - Morocco				
Al-Hasanneya School, Casa Blanca	1081	89	12	1986
National School of Engineering & Arch.	203	7	29	1986
National School of Barages and Roads	54	17	3	1986
National School for Metallic Industries, Rabat	369	57	7	1986
5 - Tunisia				
National School for Engineers, Tunis	1145	105	11	1985
National School for Engineers, Sfax	500			
National School for Engineers, Gabes	500			
National School for Engineers, Monastir	500			
National School for Engineers, Gafsa	500			

* Source Reference [64]

TABLE VII.5: AVAILABLE ENGINEERING DEPARTMENTS IN THE NORTH AFRICAN UNIVERSITIES

Engineering Discipline	Algeria	Egypt	Libya	Morocco	Tunisia
Civil	X	X	X	X	X
Architectural	X	X	X	X	X
Electrical	X	X	X	X	X
Mechanical	X	X	X	X	X
Chemical	X	X	X	X	X
Computers			X	X	X
Industrial			X	X	X
Petroleum Production	X	X	X		
Mining		X	X	X	X
Systems & Control			X	X	X
Irrigation & Drainage				X	X
Marine		X	X	X	X
Nuclear		X	X	X	X
Aeronautical			X	X	X
Geological		X	X		X
Textile & Weaving		X		X	X
Surveying		X			X
Bio-Medical		X			
					X

ANNEX VIII

NORTH AFRICAN COUNTRIES' MANUFACTURING CAPABILITIES

A major goal identified by the North African Countries is the achievement of eventual self-sufficiency in design, manufacturing, operation and maintenance of NPPs. To achieve this goal, an adequate supply of trained manpower, additional and improved manufacturing facilities, the necessary financial resources and strong Government commitment to the nuclear power programme, are necessary.

Evaluations of national manufacturing capabilities with respect to nuclear power and desalination equipment were carried out in some NACs [65-74] to various degrees of details and sophistication. Therefore, Regional manufacturing capabilities are reviewed below on a country basis.

VIII.1 ALGERIAN MANUFACTURING CAPABILITIES

Detailed analysis of the potential for the Algerian national participation in a Regional nuclear desalination project is not available at present. However, a recent survey of Governmental boilers manufacturers in Algeria indicated that the existing heavy industries within the country are involved in manufacturing petro-chemical and power plants components. For example, local participation of the 750 MW fossil power plants constructed in Algeria reached 60% and 75% for the Ras Djint and Jijel power plants respectively [66]. Special metals and alloys such as stainless steel are not produced currently in Algeria. However, there are plans to build a large plant (AFS) for alloys production in the near future.

Local manufacturing capabilities in Algeria of some target commodities relevant to power and desalination equipment are listed in Table VIII.1. Non-destructive testing and quality assurance of welds, as well as, certification of welders is performed by Unite de Development des Techniques de Soudage et de Control Non Destructive (UNTSCND) of the Ministry of Technology and Research. UDTSCND has been involved in the construction and repair of boilers for a number of years [66].

VIII.2 EGYPTIAN MANUFACTURING CAPABILITIES

A major goal of the Egyptian Government is to minimize the foreign currency expenditures associated with new developmental projects through maximizing local participation. To this end several local participation studies associated with the Egyptian nuclear power programme were carried out [67-73]. Preliminary investigation of local manufacturing capabilities of desalination equipment was also performed [74]. The main findings of these studies are summarized below.

VIII.2.1 Manufacturing Capabilities of Power Plants Equipment

In February 1989, a comprehensive study to assess the Development of Industrial Capability in Egypt (LOCALIZATION) was initiated by a consortium of AECL and NPPA. The project consists of three distinct programs, namely:

- The Equipment Fabrication (COMPONENT) program.
- The Fuel Technology (FUEL) program.
- The Heavy Water production program.

The LOCALIZATION study builds upon earlier studies [67-68] related to the introduction of 4 x 600 MW CANDU units to the Egyptian grid by the year 2000.

(a) COMPONENT program

The program consists of six Tasks representing three distinct phases. These are:

- Task 1: Component Demand Determination (completed July 1989).
- Task 2: Egyptian Industrial Survey (completed November 1989).
- Task 3: Industrial Investment Planning (completed June 1990).
- Task 4: Localization Cost Benefit Analysis (February 1991).
- Task 5: Component Localization Recommendation (February 1991).
- Task 6: Localization Program Implementation.

The first three Tasks are the search phase. The Selection phase consists of Tasks 4 & 5, and the Implementation phase is Task 6.

Task 1 was concluded by identifying a list of attractive groups of equipment as targets for local manufacturing from a percent of total value point of view [69]. The list is summarized in Table VIII.2 which shows values of components needed for additional power generation units anticipated between 1992 and 2000 in the Egyptian Electricity Expansion Plan (EEEP).

Under Task 2 of the COMPONENT program, an updated expanded survey that targets both fossil and CANDU components manufacturing capability assessments for a select group of local suppliers, was conducted. A total of 32 local suppliers were surveyed and 9 of these were surveyed twice [70]. Tasks 2 was concluded by ranking the local companies for the various target commodities as given in Table VIII.3. The leading local candidate is designated by a "1" entry in the Table, with ascending numbers assigned to lesser favored companies. The results of the industrial survey indicated that the Egyptian heavy industrial capabilities are quite limited. This lead to the suggestion for the consideration of dedicated facilities as listed in the last column of Table VIII.3.

Under Task 3, the necessary investments to upgrade individual local companies to enable the local manufacturing of the target components at the local companies or in new dedicated facilities were evaluated [5]. The evaluation carried out under Task 3 fell in three categories :

- Dedicated new facilities for boiler, turbine-generator and heat exchanger.
- Reactor components (covering eighty eight components) that were recommended by AECL to be manufactured at eleven local companies.
- Four sample evaluations for pipe fabrication, pipe hangers and supports, pumps and valves at four local companies.

Table VIII.4 Gives an overall summary of Task 3 results. It is estimated that 1374.7 million US$ will be localized forming 37.4% of the EEEP with an approximate total investment of 511 millions US$. These estimates exclude upgrading of feed industries. The investment amounts to about 13.9% of the total of equipment needed for the EEEP. At the end of the EEEP a substantial local content of the order 75-80% will be available.

Under the cost benefit analysis Task 4 [72], two types of analyses were undertaken, namely, Macro Analysis and Micro Analysis. The former is an optimization to serve as a guide to the decision makers in making the appropriate selections for upgrading the industrial capabilities in Egypt to localize equipment to the maximum extent possible to yield maximum benefit possible. The latter encompassed a profitability analysis for the local companies to assess the attractiveness of the investments for the company. The Macro and Micro Analyses were performed for each of the three categories noted above, one category at a time.

Under Task 5, a selection procedure to establish priority among candidate options was utilized to narrow down the list of candidates for upgrading in the implementation phase in the light of the results of the macro and micro analyses. The selection yielded the following six candidates [72]:

LOCAL COMPANY TARGET COMPONENT(s)

- Military Factory 999. Hangers and Supports.
- Cairo Oil Refinery. Pipe Fabrication.
- AOI Sakr Factory Reactor Components - A.
- Military Factory 100 Reactor Component - B.
- AOI Engine Factory Pumps.
- EVACO Valves.

Task 6 is currently being carried out, where detailed plans for upgrading of the six facilities to localize the target product-lines will be made.

(b) FUEL Program

A survey of the Egyptian capabilities to manufacture nuclear fuel was carried out in 1984 as part of the joint feasibility study for a CANDU program in Egypt [67]. The survey indicated that U_3O_8 concentrates could be produced within the Nuclear Material Authority (NMA). The assessment of fuel fabrication capability in the Department of Metallurgy of the Atomic Energy Authority (AEA) of Egypt indicated that a capacity already exists to produce limited quantities of UO_2 powder from U_3O_8 concentrates, and to fabricate small numbers of fuel elements (individual rods).

In 1986, a technology transfer program building on the above mentioned capability and directing the efforts towards the goal of full scale production facility was greed upon by Egyptian and Canadian representatives [68]. The program consisted of the following four phases :

phase 1: Manufacture and irradiate Experimental fuel elements
phase 2: Manufacture and irradiate tow fuel bundles.
phase 3: Manufacture and irradiate in a power reactor 100 fuel bundles.
phase 4: Manufacture fuel for an Egyptian CANDU power Reactor

A limited fuel technology transfer program comprising phases 1 & 2 above is currently being carried out [73].

(c) HEAVY WATER Program

Heavy water, or deuterium oxide (D_2O), provides the high moderating efficiency which permits the use of natural uranium fuel in CANDU reactors. AECL recommended a heavy water supply program which includes the purchase of heavy water for the initial fill of the four units and, the construction of a 20 ton/year capacity plant to supply the yearly make-up demand when the four units are in operation. For Egypt, this option means minimum capital expenditure in heavy water plants, while at the same time giving self sufficiency for continued plant operation by producing domestically the make-up requirements for the total CANDU program.

A Combined Electrolysis and Chemical Exchange (CECE) plant operating in conjunction with KIMA Chemical facility in Aswan could produce approximately 20 ton/year. The CECE uses the wet-proofed catalyst developed by AECL to pre-enrich the feed to an electrolytic cell by transferring deuterium from the hydrogen to the incoming water feed.

VIII.2.2 Manufacturing Capabilities of Desalination Equipment

The LOCALIZATION study presented in the previous section is very much relevant to the manufacturing capabilities of desalting equipment because of the common components between power and desalination plants such as: pressure vessels, pumps, valves, heat exchangers, etc. However, it might be useful to present here, the results of an earlier study specific to desalination that was carried out by FRCU [74].

The FRCU study identified the technical packages attractive for local manufacturing. These were:

- Direct desalting components.
- Pumping Package.
- Atmospheric and pressure vessels.
- Measurement and control.
- Others including piping, valves and fittings.

The most important manufacturing capabilities of some leading Egyptian companies required for local manufacturing of desalination equipment are depicted in Table VIII.5. The level of manufacturing capabilities in the Table are designated A, B, and C. Level-A refers to utilities capable of producing required items or services without loss of time or material. Level-B indicates that producing components, services or materials to the required specifications will be done with substantial loss of time and material. Level-C indicates that upgrading or modification of facility is required.

VIII.3 LIBYAN MANUFACTURING CAPABILITIES

Libyan economy is centrally planned. A major objective declared by the Libyan Government is to maximize local participation. To this end, several organizations, companies and firms were set-up to provide the basic industrial infrastructure. The related industries are briefly discussed below.

VIII.3.1 The Musrata Iron and Steel Complex

The complex is the second largest industrial complex, preceded only by the National Oil Foundation. The annual production of carbon steel products is more than 1.3 million tons. The planned extension of the complex will increase the annual production to 2.0 million tons, and will produce special alloys and stainless steel which are not produced in the time being.

The line of production includes all steel sections needed for industry and construction such as bars, rods, channels, beams and sheets (cold and hot rolling). Governmental statistics indicated that, in 1991, the basic metallic industries represented 44% of the total Libyan industrial production, with a value of about 145 million Libyan Dinars.

VIII.3.2 Basic Engineering Industries

The main industrial establishment in this sector is the Organization of Engineering Industries (OEI), which consists of a number of separate modern workshops. OEI has the capability to perform all basic manufacturing process such as: casting, forging, machining, welding and heat treatment.

There is no specialized companies in Libya to produce the basic components and equipment of desalination units such as pumps, motors, pressure vessels, heat exchangers, etc. However, some components can be manufactured at OEI facilities provided that the necessary up-grading of AQ/QC is carried out.

VIII.3.3 Civil and Electro-mechanical Erection Companies

There is a number of private and governmental construction companies, with good experience in construction and erection works, particularly in civil engineering, water pipelines, pumping stations, and electrical transmission lines. Some of these companies are listed in Table VIII.6.

VIII.3.4 Codes and Standards

The codes and standards currently in use in Libya rely on internationally accepted standards such as ASME, BS, DIN, etc. The adoption of any of these codes and standards depends on the country of origin of the particular factory, equipment or component. Recently, Libya started to compile its own codes and standards. However, this is still in a very preliminary stage. The institutions responsible for performing this task are:

- Center of Industrial Research.
- National Center for Specifications and Standards.

VIII.4 MOROCCAN MANUFACTURING CAPABILITIES

The Moroccan manufacturing capabilities are quite developed, albeit small in size. Many of the manufacturing companies in Morocco are joint venture companies. The products include items like pumps for irrigation, valves, industrial boilers, circuit breakers, batteries and switch boards. The local share of these products is up to 50%, which is a high percentage taking into account that iron and steel, and alloys are not produced locally.

There is also a large manufacturing capabilities in various smaller firms possessing modern capabilities for casting, welding, forging, machining, plating, tubing and heat treatment. Tables VIII.7 - VIII.9 list some of the Moroccan manufacturing capabilities in various fields.

The Public Laboratory of Studies and Testing (PLST), which is owned jointly by the governmental and private sectors, provides essential and basic studies for new projects in Morocco. PLST consists of a number of specialized laboratories located in various Moroccan cities, and could provide good services for any future desalination project in Morocco. The range of services includes hydrology, seismic studies, geology, NDT, siting, etc.

VIII.5. TUNISIAN MANUFACTURING CAPABILITIES

In 1988, a survey of Tunisian industries was made to determine the degree of possible national participation in power plants projects. The results of the survey can be extended, with the necessary updates, to the participation in Regional nuclear desalination project.

Generally, the industrial sector has the capacity to start a manufacturing program in the following fields:

- Heat exchangers, pumps, pipes, valves.
- Tanks for water storage and chemical feeding
- Transformers, cables, switchboards, motors, lighting and insulation.
- Measurement and control.

However, the companies differ from one another in level of participation in this program. They may be classified into three categories :

- Category A: The companies which can immediately produce components or perform services without any change in their manufacturing process. They have qualified and experienced manpower as well as modern equipment. They supply the dairy industry and the electrical, chemical and hydrocarbon sectors with heat exchangers, pumps, cranes, motors, in accordance with quality requirements.

- Category B: The companies which are well structured and organized to act as subcontractors for some components. But they need financial resources, to their workshops and train employees.

- Category C: The companies which require special upgrading programs, recruitment of manpower, or purchase of modern equipment.

Tables VIII.10, VIII.11, and VIII.12 show the breakdown of companies by categories for three fields: civil engineering, mechanical and electrical equipment.

TABLE VIII.1: LOCAL MANUFACTURING CAPABILITIES IN ALGERIA (1)

Target Commodity	Candidate Manufacturer
- Power Plants Boilers	ENCC / Oran III & Annaba II
- Medium size Industrial Boilers	ENCC / Relizane
- Domestic Boilers	ENCC / Relizane
- Pressure Vessels	ENCC / Oran III & Annaba II
- Heat Exchanger Tubing	Sider Plant / Annaba
- Surface Condensers	ENCC / Oran III & Annaba
- Castings	Tiaret Foundary
- BOP Pumps	CPV (2) - Berrouaghia
	Reghaia Pumps
- BOP Valves	CPV - Berrouaghia
- Heat Exchangers	ENCC (3) / Oran III, Cote Rouge & Annaba II
	ENCC / Cote Rouge
- Cranes	ENCC / Oran III & Annaba II
- Thin Wall Vessels	Anabib Plant / Reghaia
	Anabib Plant / Reghaia
- Fabricated Piping	ENCC / Cote Rouge
- MSF Evaporators	Bliba Heavy Machinaries
	ENCC / Oran III, Cote Rouge & Annaba II
- Petro-chemical Distillation Columns	

(1) Source Reference [40]
(2) CPV - Berrouaghia = Complexe Pompes et Vannes de Berrouaghia
(3) ENCC = Entreprise Nationale de Charpente et Chaudronneti

TABLE VIII.2: SUMMARY OF COMPONENT GROUPS VALUES

Rank	Component Group	Present Value ($million) Nuclear	Fossil	Sum	Sum % of TV
1	Generators - STG's	317.3	383.0	700.3	19.05%
2	Boilers Fossil	0.0	529.0	529.0	14.39%
3	RCTR. Comps.	317.5	0.0	317.5	8.64%
4	(Calandria)	215.0	60.0	275.0	7.48%
5	Heat Exchangers	0.0	241.5	241.5	6.57%
6	Gas Scrubbers	124.7	107.0	231.7	6.30%
7	Pipe & Fittings	103.1	51.0	154.1	4.19%
8	Pumps	107.0	39.9	146.9	4.00%
9	Valves	105.5	20.4	125.9	3.43%
10	Misc. Electrical	0.0	192.3	192.3	5.23%
11	Combus. Turb. Gen.	69.7	27.8	97.5	2.65%
12	Misc. Mechanical	0.0	85.3	85.3	2.32%
13	Coal Hndi System	43.0	41.7	84.7	2.30%
14	Xrmrs, Main, Aux.	49.2	22.4	71.6	1.95%
15	Misc. Instruments	30.3	36.9	67.2	1.83%
16	Cable, Wire	11.3	40.9	52.2	1.42%
17	Water Treatment Eq.	15.5	24.0	39.5	1.07%
18	DCS, Computers	7.9	23.1	31.0	0.84%
19	MCS, Switchgear	30.3	0.0	30.3	0.82%
20	Switchyard Equipment	24.7	5.4	30.1	0.82%
21	Elect. Panels, Relays	24.1	6.0	30.1	0.82%
22	HVAC	0.0	31.0	31.0	0.84%
23	Stack, Chimney	13.6	13.0	26.6	0.72%
24	Cranes, Permanent	0.0	25.5	25.5	0.69%
25	Elect. Precip.	19.3	3.4	22.7	0.62%
26	Tanks - Shop	3.8	16.0	19.8	0.54%
27	Tanks - Field	3.8	12.8	16.6	0.45%
	Conduit, Trays				
	Total US $ millions	1636.6	2039.3	3675.9	100 %
	% total value	44.52	55.48	100	

TABLE VIII.3: EGYPTIAN INDUSTRIAL SURVEY TARGET COMMODITY / / LOCAL MANUFACTURING RECOMMENDATION

LOCAL SUPPLIER	MINISTRY OF INDUST.									MILITARY FACT.						
TARGET COMMODITY	IRON & STEEL	ALEX SHIPYARD	SUGAR FACTORY	NASR BOILER	NASR FORGING	NASR St. PIPES	NASR CASTINGS	METALCO	STEELCO	FACTORY 63	FACTORY 99	FACTORY 999	FACTORY 100	FACTORY 9	FACTORY 54	FACTORY 144
BOILER PRESSURE PARTS		2		3												
BOILER STRUCTURAL PARTS	7	5	4					3	2							
HEAT EXCHANGERS - FEEDWATER HEATERS																
HEAT EXCHANGERS - SURFACE CONDENSERS									2							
HEAT EXCHANGER TUBING																
STEEL - STRUCTURAL GRADE	1															
TURBINE SMALL BLADES																
TURBINE SOLE PLATES / FOUNDATION PLATES												1				
TURBINE SMALL PARTS EXCLUDING BLADES													3			
FORGING - PUMPS AND VALVES					1											
MACHINED FORGINGS - PUMPS AND VALVES															1	
CASTINGS - PUMPS AND VALVES	2													1		
API WELDED PIPE						1										
CAST IRON PIPE							1									
SUBCONTRACTED SHAFT MACHINING							1									
NUCLEAR AND BOP VALVES																
INSTRUMENT VALVES																
BOP PUMPS																
NUCLEAR PUMPS																
CANDU SPEC. COMP. - CHAN. CLOSU. / SHIELD PLUGS																
CANDU SPEC. COMP. - SHUT - OFF / ADJUSTOR DRIVES																
CANDU SPEC. COMP. - SLEEVES													2			
CANDU SPEC. COMP. - LATTICE TUBES													2			
CALANDRIA VESSEL																
STEAM GENERATOR																
CANDU S&T HEAT EXCHANGERS AND SMALL TANKS				2												
STRUCTURAL AND MISCELLANEOUS St. FAB.								3	2							
PLATE AND SHEET FABRICATION									2							
AIRLOCKS AND HATCHES																
SPENT FUEL STORAGE RACKS																
CRANES								2	1							
LIGHT WALL VESSELS																
MISCELLANEOUS SHELL & TUBE HEAT EXCHANGERS																
FABRICATED PIPING																
HVAC												1				
LARGE POWER TRANSFORMERS																
SWITCHBOARDS, PANELS, SWITCHGEAR																
POWER CABLE																
ELECTRONIC COMPONENTS - CONTROL SYSTEMS																2
ELECTRONIC COMPONENTS - SIMULATORS																2
CABLE TRAYS																

TABLE VIII.3: EGYPTIAN INDUSTRIAL SURVEY TARGET COMMODITY / / LOCAL MANUFACTURING RECOMMENDATION (cont.)

LOCAL SUPPLIER	AOI					GUE		ELE		P	A	PRIVATE					
TARGET COMMODITY	AIRCRAFT FACTORY	ENGINE FACTORY	SAKR FACTORY	KADER FACTORY	ELECTRONICS FACTORY	ELTEMSAH SHIPYARD	PORT SAID SHIPYARD	ELMACO	EGEMAC	CAIRO REFINERY	ARABB	FERROMETALCO	EVACO	WAYLER FARID	EMG	ELSWIEDY	
BOILER PRESSURE PARTS																	1
BOILER STRUCTURAL PARTS						6						1					
HEAT EXCHANGERS - FEEDWATER HEATERS																	1
HEAT EXCHANGERS - SURFACE CONDENSERS												1					
HEAT EXCHANGER TUBING																	1
STEEL - STRUCTURAL GRADE																	
TURBINE SMALL BLADES		1															
TURBINE SOLE PLATES / FOUNDATION PLATES		2					3										
TURBINE SMALL PARTS EXCLUDING BLADES		1	2				4										
FORGING - PUMPS AND VALVES																	
MACHINED FORGINGS - PUMPS AND VALVES																	
CASTINGS - PUMPS AND VALVES																	
API WELDED PIPE																	
CAST IRON PIPE																	
SUBCONTRACTED SHAFT MACHINING																	
NUCLEAR AND BOP VALVES													1				
INSTRUMENT VALVES	2												1				
BOP PUMPS		1															
NUCLEAR PUMPS		1															
CANDU SPEC. COMP. - CHAN. CLOSU. / SHIELD PLUGS		1	2														
CANDU SPEC. COMP. - SHUT - OFF / ADJUSTOR DRIVES		1	2														
CANDU SPEC. COMP. - SLEEVES		1	3														
CANDU SPEC. COMP. - LATTICE TUBES		1	3														
CALANDRIA VESSEL							1										
STEAM GENERATOR																	
CANDU S&T HEAT EXCHANGERS AND SMALL TANKS										1							
STRUCTURAL AND MISCELLANEOUS St. FAB.												1					
PLATE AND SHEET FABRICATION				1													
AIRLOCKS AND HATCHES				1													
SPENT FUEL STORAGE RACKS				1													
CRANES																	
LIGHT WALL VESSELS										1							
MISCELLANEOUS SHELL & TUBE HEAT EXCHANGERS										1							
FABRICATED PIPING						1				2							
HVAC																	
LARGE POWER TRANSFORMERS								1									
SWITCHBOARDS, PANELS, SWITCHGEAR									1		2				3		
POWER CABLE																1	
ELECTRONIC COMPONENTS - CONTROL SYSTEMS					1												
ELECTRONIC COMPONENTS - SIMULATORS					1												
CABLE TRAYS	1																

TABLE VIII.4: OVERALL SUMMARY OF TASK 3 RESULTS

	Groups Value $million (I)	Localized Value $million (II)	Invest. $million (III)	Loczd to Value % (IV)	Loczd to Invest. Ratio (V)
Extended Groups Dedicated					
Subtotal (1)	1872.3	499.7	233.6	26.69	2.1
RX Group					
AECL Recommended					
Untackled	121.5				
Subtotal (2)	317.5	62.4	42.9	19.66	1.5
Primary Groups Pipe & Pumps & Valves					
Samples	239.8	117.9	76.2	49.15	1.5
Balance [A]	292.5	82.3	78.1	28.14	1.1
Subtotal (3)	532.3	200.2	154.3	37.6	1.3
Sum (1, 2, 3)	2722.1	762.3	430.8	28	1.8
Net sum (4) [1]	2655.1				
Electrical & Remaining Mechanical [3]					
Remain. Sec. (5) [B]	1020.8	612.5	80	60	7.7
TOTAL (4, 5)	3675.9	1374.8	510.8	37.4	2.7
% OF TOTAL EEEP VAL..		37.4 %	13.9 %		

(I): Total value of group(s)
(II): Localized value
(III): Investments
(IV): The percentage localized of the total value of the group(s) (column II to I)
(V): Ratio of localized value to investments (column II to III)

[A]: Inferred localized Value and Investments for the remainder of the value of the primary groups; pipe, pumps and valves.

[B]: Inferred localized Value and Investments for the remainder of the value ot the remaining secondary groups.

[1]: Excluding CALANDRIA value to be localized at HX dedicated facility and internal valves in the valves sample.

TABLE VIII.5: MANUFACTURING CAPABILITIES OF EGYPTIAN INDUSTRY

	NASR BOILER & PRESSURE VESSELS	IRON & STEEL	EL-NASR STEEL PIPING & FITTING	STEELCO	FACTORY 63	FACTORY 9	FACTORY 909	FACTORY 999	FACTORY 100	FACTORY 100	EGYPTIAN VALVE COMPANY	A.O.I. ENGINE	HEAT - CO.	ALEX SHIPYARD	METALCO	GENERAL COMPANY FOR IRRIGATION VALVES	NASR AUTOMATIVE
HYDRAULIC PRESS	B				B					A				B			
HEAT TREATMENT	B	B			B					A		B		B		B	B
ROLLING	B	B		A				A					B	B	B		
PLATING	B	C	A	A	C			B		A		B		B	B	B	A
CASTING RO					A	A				A	A	B				A	A
MACHINE TOOLS (lathes, boring, cutting)	A				C		A	A		A	A	B	B	A	B	A	A
TESTING	X-ray		Ultra-sonic		Ultra-sonic							X-ray	X-ray	X-ray - Ultra	X-ray - Ultra		

TABLE VIII.6: LIBYAN ENGINEERING CAPABILITIES

Company/Organization	Production/Activity
1. Iron and Steel Complex	Carbon steel products including the following: - bars, rods, channels, beams, slabs - cold and hot rolled coils and sheets
2. Organization of Engineering Industries 3. Benghazi Central Workshop	- Casting, forging, welding, machining and heat treatment
4. General Company for Chemical Industries	- Sodium Hydrozide - Hydro-choric acid - PVC Powder
5. General Company for Pipes	- Longitudinal welded pipes - Helical welded pipes
6. National Company for Pipes	- Asbestos pipes - PVC pipes
7. General Company for Cables and Electric Products	- Power cables - Wires
8. Construction and Metal Works Company	- Steel structures and hangers - Tanks ≤ 100 m^3
9. Electric Construction Company (ECCO)	Erection of: - Power stations - Overhead transmission lines ≤ 66 kV - Underground cables Production of: - Distribution Boards - Solar cells
10. Arab Union Company	- Civil engineering contractors - Producers of construction materials
11. African Engineering Company	- Contractors specialised in civil and electromechanical works.

TABLE VIII.7: MORROCAN METALIC INDUSTRIES

CODE	001	005	002	003	026	042	006	004	007	009	011	012	008	013	024	043	014	015	016	010	038	018	039	027	028	019	025	020	022	023	037
NAME	AFOMA	AFS	AGAPLEX	ALU-COQUILLES	ATEUR D AIN SEBAA	BATIFIER	FAM	FAMAB	FM	FONDERIE D OUJDA	FONDERIE SOCAFER	FONTEC	FTM	FUMA	GABRIELE S.N.C.	INDUSTUBE	J.L.M.	MAFODER	MAG METAL	MAGHREB FONDERIE	MAGHREB TUBE	MAROC FONTE	MAROMETAL	MIDAKHAT ROTAXE	SFIANI ENTREPRISE	SIMEF	SMCV	SMFN	SOFAMI	SPECTRO MAROC	TUBE AT PROFIL
Cast - iron	X	X	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X	X		X		X	X	X	X	X	X	X	
Non ferous metals	X		X	X				X	X	X			X					X		X											
Alloys	X		X	X					X									X	X											X	
Casting	X	X	X					X			X	X																			
Heat treatment							X																								
Surface treatment																			X												
Galvanization						X										X					X		X								X

TABLE VIII.8: METALIC AND MECHANICAL CAPABILITIES IN MOROCCO

CODE	064	065	003	154	066	055	026	031	042	045	068	089	067	046	169	041	034	047	069	070	071	057	011	012	072	033	036	029	160
NAME	ACAS	AIC	ALU-COQUILLES	AMF	AMZ	ATCOMA	ATELIER D AIN SEBAA	BABCOCK WANSON	BATIFER	BUZZICHELLI MAROC	CAM	CEN	CGT	DELATTRE LEVIVIER	DIMATIT	DOLBEAU	EGFI	ELECAM	ENATCOM	ENTREPRISE EL WEHDA	ETS DEPASTAS	FLORES MARCEL	FONDERIE SOCAFER	FONTEC	GIORDANO & FILS	GUINGAND	HIERRO	ICAT MAROC	IHM
Metalic construction												X																	
Mechanical construction																			X										
Thermal equipments																	X												
Sheet metal works	X	X			X	X		X		X	X		X	X					X	X	X				X				
Tanks				X	X	X								X			X					X							
Boilers (industrial)							X	X									X									X	X	X	
Industrial furnaces (metals)																	X												
Cooling towers																												X	
Heat exchangers						X											X												
Iron structure	X	X			X		X							X					X	X	X				X				
Tubes								X	X							X													
Tubes (fittings)																X													
Pumps (manufacture)																													
Pumps (fittings)																							X						
Valves & cocks			X												X									X					X
Cutting																													
Sheets profiling									X																				
Sheets plating																													
Forging																													
Pipe works		X			X			X		X	X		X	X				X	X	X	X	X							
Design																													
Machining & tooling																													

TABLE VIII.8: METALIC AND MECHANICAL CAPABILITIES IN MOROCCO

CODE	043	115	074	116	044	073	016	076	017	018	170	155	021	027	058	077	078	079	040	063	080	050	035	082	059	147	060	153	085
NAME	INDUSTUBE	INMETA	INTERMECANIQUE	J.M.INDUS	LE PROFILE	LETIT MAROC	MAG METAL	MALTESSE	MARIBU	MAROC FONTE	MECA INOX MAROC	MECAFER	METAGHREB	MIDAKHAT ROTAXE	MOHTAREM	MSM	PACOMETAL	PLA	PROFILMA	PROMINEX	ROSSELL	ROUX PIERRE	SAMATIC	SAMETAL	SATECOM	SATMA	SCIF	SEBTEC	SEM
Metalic construction													X				X	X			X	X			X				
Mechanical construction			X															X											
Thermal equipments																													
Sheet metal works			X			X		X								X	X	X		X	X	X	X	X	X		X		X
Tanks												X	X												X		X	X	
Boilers (industrial)																													
Industrial furnaces (metals)		X		X																									
Cooling towers																													
Heat exchangers																													
Iron structure																		X			X			X	X				
Tubes	X				X																								
Tubes (fittings)																													
Pumps (manufacture)														X												X			
Pumps (fittings)														X															
Valves & cocks											X		X																
Cutting							X																						
Sheets profiling																													
Sheets plating					X														X										
Forging							X																						
Pipe works						X									X		X			X		X	X		X				
Design									X																				
Machining & tooling							X		X	X																			

TABLE VIII.8: METALIC AND MECHANICAL CAPABILITIES IN MOROCCO

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CODE	081	051	019	149	052	054	025	171	020	061	159	030	022	162	150	062	157	158	084	151	086	053	087	161					
NAME	SIDEN	SIERI	SIMEF	SMADIA	SMCI	SMCM	SMCV	SMEM	SMFN	SMPC	SNRO	SOCOCHARBO	SOFAMI	SOFIMETAL	SOFRAMAR	SOGENEXE	SOMAMA INDUSTRIE	SOMAROBINET	SOMATIC	SOTEMAG	THERMOS	UIM	UMCI	VENTEC MAROC					
Metalic construction																													
Mechanical construction								X																					
Thermal equipments																													
Sheet metal works	X					X				X		X							X		X		X						
Tanks					X							X					X												
Boilers (industrial)												X																	
Industrial furnaces (metals)																													
Cooling towers														X										X					
Heat exchangers																													
Iron structure	X	X			X					X						X							X						
Tubes						X							X																
Tubes (fittings)													X																
Pumps (manufacture)			X	X											X					X									
Pumps (fittings)																													
Valves & cocks							X				X							X											
Cutting																													
Sheets profiling																													
Sheets plating																													
Forging																													
Pipe works		X			X					X						X			X			X	X						
Design																													
Machining & tooling			X					X	X														X						

TABLE VIII.9: MOROCCAN INDUSTRIAL CAPABILITIES IN ELECTRIC WORKS

CODE	056	140	141	045	068	088	089	142	090	091	047	092	143	070	144	145	093	057	094	095	132	096	049	063	097	098	099	028	051	052	117	062	146
NAME	ATRIAL	BAHJA	BELKHALFI	BUZZICHELLI MAROC	CAM	CCEE	CEN	DERIE	EEG	ELCOTRAM	ELECAM	ELECOM	EMT	ENTREPRISE EL WEHDA	ENTREPRISE ZAHID	ETS ROUISSI	FEDELEC	FLORES MARCEL	GEPROD	LUMAFRIC	MAGHREB PROJETS	MARFLE	MAROC MONTAGE	PROMINEX	PROTELEC	REDOUANI	SCEI	SFIANI ENTREPRISE	SIERI	SMCI	SMESI	SOGENEXE	ZINETEC
Plants setting up				X	X									X				X			X		X	X					X	X	X	X	
Industrial electricity works	X					X	X		X	X		X					X		X	X		X			X	X	X						
Pumping installation	X	X	X			X		X	X		X		X		X	X						X						X					X

TABLE VIII.10: CIVIL ENGINEERING CAPABILITIES IN TUNISIA

	AFRIQUE TRAVAUX	CETIME	CHAUFOUR DUMEZ	ECME	EL FOULEDH	EL ISKAN	FONDERIE MODERNE	FONDERIES REUNIES	CENERALE DE PRECONTR.	GLASSWORKS	IMD	IMEN	MHENI	SABOURIN	SAMI	SCIN	SEPST	SGI	SIFF	SOCOMENIN	SOMATRA	SONIM	SOTUCOM	STC	TECHNIFER
Buildings			A			A							A								A				
Constructional material																								A	A
Duck boards																A									
Dykes											A	A													
Earth works						A																			
Foundations													A								A				
Framework				A	A									B				A		A					
Iron for concrete					A										A			B							
Metallic joinery							B								A										B
Painting																	A						A		
Piping				A				B		A				A											
Plastic																								A	
Plating		A				A	B								A										
Prestressed concrete									A				A									B			
Quarry workings													A					A						'	
Reinforced concrete	A		A			B			A													B			
Roads			A				A						A												
Steel for casing					A																				

TABLE VIII.11: MANUFACTURING CAPABILITIES OF MECHANICAL EQUIPMENT IN TUNISIA

	AFRIC ISOL	AFRICA INDUSTRIES	ATLAS POMPES	AMS	CHAFRA	ECME	EL FOULEDH	IDEAL DESIGN	IMAL	INCO MANUTENTION	TMK	HYDROMECA	MISFA	SACEM	SABOURIN	SAMOU	SCIN	SGI	SICAM	SIMET	SOGEFU	SOFMOMECA	SOCOMENA	SOCOMENIN	SONIN	SOTAL	STAMINOX	TECHNIFER	TOFCO	TPR	TUNIS ALU	TUNISIE MANUTENTION	VDI	L'OUTILLAGE
Compressors						A																												
Copper processing				A																														
Cranes						A				A						A	A																	
Diesel generators			B																															
Fans	A																																B	
Filters													A																					
Girders										A							A	A															B	
Heat Exchangers															A		A	A						A										
Lifts, elevators																																A		
Metallurgy							A																											
Monorail										A							A																	
Moulded and wrought parts																							A	A										
Piping					B	A									A									A					B					
Pumps		A	A									A		A																				
Sectional irons																		A											B					
Separators																																	B	
Sheet steel							A																											A
Soldering machines																																		
Steel frames							A											A			A													
Steel yarns							A																											
Tackles						A				A							A	A																
Tanks						A									A								AA	A				A						
Tools																																		A
Valves								B																	B									

TABLE VIII.12: MANUFACTURING CAPABILITIES OF ELECTRICAL EQUIPMENT IN TUNISIA

	ARABTEL	ATEM	CHAKIRA	CTL	EL MOUHAOUEL	INDEL	NORMELEC	SACEM	SCEME	SIAME	TET	TTE	TUMELEC	TUNISIE TRANSFORMATEURS	WEIGAND TUNISIE	WERDA
Cables			A		A					A						B
Circuit breakers										A		A				
Electrical connections		A														
Lighting				A												
Measurements										A	B			A	A	
Motors								A								
Panels											A	A				
Relays											A					
Switchboards							A		B		A	A				B
Telephony	B						B									
Transformers					A	A		A						A		

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DEFINITIONS

The following are used throughout the report:

- Available Water Resources	The portion of water resources that is controlled and can be used whenever needed through the existing water facilities.
- Contiguous Plant	Power plant jointly located with desalination plan with shared seawater intake / outfall structures.
- Dedicated Power Plant	Power plant not connected to the electrical grid. Total production capacity is dedicated to supply the desalination plant with energy.
- Desalination Plant	Installations Comprising all buildings, structures, systems and components necessary to produce potable water from saline water, with an input of energy, in produce potable water from saline water, with an input of energy, in form of heat and electricity, or electricity only.
- Dual-Purpose Plant	Reactor or fossil-fired power plant with a product output of both heat (steam or hot water) and electricity. It is to be noted that the concept of "dual-purpose" (and "single-purpose") plant is sometimes used in a different sense in the energy source and desalination complex. "Dual-purpose" in this sense would mean a desalination complex supplying simultaneously electricity to the grid (or an outside consumer) and producing desalinated water. Single-purpose" would mean that the only product of the complex is desalinated water. This interpretation of the term "dual-purpose" (and single- purpose) is not applied in the present report in order to avoid confusion.
- Membrane process	Desalination process based on the use of membranes. Energy input is in the form of electricity.
- Nuclear Desalination	The process of seawater desalination in a facility in a which nuclear reactor is used as the source of energy for the desalination process. Electrical energy, thermal energy or a combination of electrical and thermal energy may be used in the desalination process. The facility may be dedicated solely to the production of water, or may be used for the cogeneration of both electricity and potable water, in which case only a portion of the reactor's total energy output is used for water production. In either case, the notion of nuclear desalination is taken to mean an integrated facility in which both the reactor and the desalination system are located on a common site and energy is produced on

site for use in the desalination system. It also suggest some degree of common or shared office and maintenance facilities, operations and maintenance staff, engineering staff, operating strategies, outage planning, and also possibly control facilities and intake and outfall structures.

- Potential Water Resources — The portion of water resources that can be utilized through the application of current technology and engineering.

- Power plant — Installation comprising all buildings, structures, systems and components necessary to produce energy.

- Single-Purpose Plant — Power plant with a single output (product), either heat only, or electricity only.

- Stand-Alone Plant — Power plant jointly located with desalination plant, not sharing seawater intake/outfall structures.

- Water Resources — All fresh water quantity know to exist within or enter the boundaries of a country. This is also referred to as theoretical water resources.

- Water Supply — The sustainable water that can be produced by the existing water facilities in a particular time. Water supply can be less than or equal to the available water resources.

- Water Demand — The amount of water required to meet the developmental needs specified by the country.

- Water Deficit — The difference between water demand and sustainable water supply at a particular time.

ABBREVIATIONS

AECL	Atomic Energy of Canada Ltd.
AGM	Advisory Group Meeting
BWR	Boiling Water Reactor
CDSE	Center de Development des Systemes Energetiques (Algeria)
CIF	Cost Insurance Freight paid
CNESTEN	Center National de l'Energie des Sciences et des Techniques Nucleaires, (Morocco)
CRIEPI	Central Research Institute of Electric Power Industry of Japan
DOE	US Department Of Energy
DPP	Distillate Production Plant
ED	Electrodialysis
EPS	Electric Power Systems Engineering Co. (Egypt)
FAO	Food and Agriculture Organization of the Unite Nations
FBR	Fast Breeder Reactor
FOAK	First Of A Kind
FOB	Free On Board
FRCU	Foreign Relations Coordinating Unit of Supreme Council of Universities in Egypt
GCR	Gas Cooled Reactors
GDP	Gross Domestic Product
GMRP	Great Manmade River Project
GNP	Gross National Product
GOR	Gain Output Ratio
HTGR	High Temperature Gas-cooled Reactor
HTME	Horizontal Tube Multi Effect distillation

IACRS	Inter-Agency Committee on Radiation Safety
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation units and Measurement
IDA	International Desalination Association
IEA	International Energy Agency
IEX	Ion Exchange
ILO	International Labour Organization
INET	Institute of Nuclear Energy Technology, (P.R. China)
INSAG	International Nuclear Safety Advisory Group
LCD	Liters per Capita per Day
LMCR	Liquid Metal Cooled Reactor
LMR	Liquid Metal Reactor
LT-HTME	Low Temperature Horizontal Tube Multi Effect distillation
ME	Multiple Effect evaporation
MED	Multi Effect Distillation
MHTGR	Modular High Temperature Gas-cooled Reactor
MSF	Multi Stage Flash distillation
MTOE	Million Tons of Oil Equivalent
MVC	Mechanical Vapor Compression
MWD	Metropolitan Water District of Southern California
NAC	North African Country
NEA	Nuclear Energy Agency
NAR	North African Region
NGL	Natural Gas Liquids

NHR	Nuclear Heating Reactor
NPP	Nuclear Power Plant
NPR	Nuclear Power Reactor
NUSS	Nuclear Safety Standards for power plants
OCP	Office Cherifien des Phosphate, (Morocco)
OECD	Organization for Economic Co-operation and Development
ONEP	Office National de l' Eau Potable, (Morocco)
OPEC	Organization of the Petroleum Exporting Countries
ORNL	Oak Ridge National Laboratory, (USA)
PAHO	Pan American Health Organization
PHWR	Pressurized Heavy Water Reactor
ppm	part per million
PWR	Pressurized Water Reactor
RO	Reverse Osmosis
SONEDE	Societe' Nationale d 'Exploration et de Distribution des Eaux, (Tunisia)
STEG	Societe Tunisienne de l'Electricite et du Gaz (Tunisia)
TDS	Total Dissolved Solids
TMI	Three Miles Island
TSS	Total Suspended Solids
TVC	Thermal Vapor Compression
UNEP	United Nations Environment Program
UNSCAER	United Nations Scientific Committee on the Effects of Atomic Radiation
USAID	United States Agency for International Development
VC	Vapor Compression
VTE	Vertical Tube Evaporator

WCR	Water Cooled Reactor
WEC	World Energy Conference
WHO	World Health Organization

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Preparatory Meeting

Vienna, Austria: 21-24 January 1991

Regional Meetings

Cairo, Egypt: 4-7 May 1991
Rabat, Morocco: 22-27 July 1991
Algiers, Algeria: 7-11 September 1991
Tunis, Tunisia: 5-9 October 1992
Cairo, Egypt: 8-11 May 1994
Vienna, Austria: 26-30 September 1994
Cairo, Egypt: 21-23 May 1995