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NATIONAL ENERGY PLAN

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N A T I O N A L

E N E R G Y

P L A N

Executive Summary

Technical and Economic Report

List of Projects

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FOREWORD

Since Independence, the Republic of Djibouti has continued to emphasize the special importance of energy in the activities and programs undertaken by the Government.

Like water and food, energy is an essential element of national development.

Possessing neither coal, petroleum, nor natural gas, Djibouti must import all of the energy supplies required for the key sectors of the economy: industry, transportation, and the generation of electrical power.

Only fuelwood can be counted as an indigenous source of energy, but it is a resource whose very use contributes to the desertification which threatens its future.

Faced with an energy bill which has been increasing year after year, the Government has decided to launch an ambitious program for the development and management of the energy sector based on the following themes:

- the development and strengthening of energy sector institutions
- increased efforts to train engineers, analysts, and technicians
- the implementation of comprehensive demand management and energy conservation measures
- the development and exploitation of indigenous energy resources.

The recent increase in the price of oil, and the unpredictability of future energy supply and demand underscores the necessity for effective national energy planning.

Djibouti possesses the manpower and the resources needed to plan for the future. Instead of an almost total dependence on the world market and its shifting prices, Djibouti will develop its national energy resources such as geothermal energy, solar energy and wind power, and will take advantage of the significant energy savings which can be realised by energy conservation.

It is this context which gives the important work carried out over the last year by analysts from ISERST, the UNDP, USAID, and VITA, its particular significance.

The MEDEE-S computer model, adapted and improved for the case of Djibouti, is a powerful tool for the modeling of energy supply and demand.

Together with a comprehensive database, which has been enlarged and brought up to date, the MEDEE-S model now provides analysts and decision-makers with the means to study the present energy situation, to forecast future energy demand, and to outline the framework of an integrated national energy plan.

This first approach to national energy planning has examined two quite different development scenarios for Djibouti. This study confirms the validity of the energy sector initiatives already underway, and recommends that the strengthened by implementing a series of priority energy sector development projects.

Aware of the social, economic, and technological impact of energy policy formulation and implementation, the Government of Djibouti fully supports the implementation of the projects set out in the National Energy Plan which will eventually bring a significant improvement in the standard of living for the population, as well as affording a significant and welcome degree of energy independence for the nation.

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The major part of this report was written by Jean-Yves Garnier, with assistance from Martin Bush, Arturo Villavicencio, Mihai Petcu, Abdourahman Farah, Yacob Nour, and Iaon Stancescu. The English translation was prepared by Martin Bush with assistance from the VITA office in Arlington, Virginia.

Among many others who contributed to this study we should mention in particular Mr. Dietre with the National Bureau of Statistics (DINAS), and Djama Ali Guele, Jean Paul Siry and Alain Roucole of Electricité de Djibouti.

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Martin Bush
Jean-Yves Garnier

ISERST, Djibouti
April 1987.

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EXECUTIVE SUMMARY

The purpose of this study of the energy sector is to formulate a long term energy policy for the Republic of Djibouti, to propose initiatives and to define objectives in the short and medium term, and to facilitate the financial support of these actions by the international donor agencies.

The aims of the study are:

- to formulate an Integrated National Energy Plan.
- To identify, describe, and present the technical and economic analyses of specific projects for which funding will be solicited.

This chapter summarizes the principal actions carried out by the project and the conclusions reached.

THE ENERGY BALANCE FOR 1985

Tables 1 and 2 present the national energy balance and the disposition of final energy for the year 1985. These balances were developed as a part of the analysis conducted for the implementation of the MEDEE-S computer model of the energy sector of Djibouti.

The main points illustrated by the energy balances can be summarized as follows:

a) Energy produced from national resources accounts for 13% of the total energy consumed in the country. The remainder is imported and is almost entirely petroleum products.

b) Of the energy consumed, losses due to conversion and distribution account for 28%. Thus, the efficiency of the energy sector in Djibouti is approximately 72%.

c) The losses due to the generation of electricity account for 80% of the overall losses. The remainder is due to the production of charcoal (7.8 %), and the losses in the transmission and distribution of electricity (12.2 %).

d) The final consumption of energy in 1985 amounted to 71,300 TPE which represents a per capita energy consumption of

TABLE 1

ENERGY BALANCE FOR THE REPUBLIQUE OF DJIBOUTI

YEAR : 1985	PRIMARY ENERGY				TOTAL PRIMARY ENERGY	SECONDARY ENERGY									
TEP	Wood	Oil	Geotherm.	Solar		Charcoal	LPG	Gasoline	Jet fuel	Kerosene	Diesel	Fuel oil	TOTAL HYDROCARB.	Electricity	TOTAL
PRODUCTION	13135				13135								0		13135
IMPORTS					0	50	658	9384	62271	9510	64521	93134	239478		239528
EXPORTS					0				-57608		-40472	-56257	-154337		-154337
TRANSFERS					0				-116		116		0		0
STOCK CHANGES					0		-30	1408		586	1701	-2926	739		739
TOTAL NATIONAL MARKET	13135	0	0	0	13135	50	628	10792	4547	10096	25866	33951	85880	0	99065
ELECTRICITY GENERATION					0						-3030	-33430	-36460	14125	-22335
PETROLEUM REFINING					0								0		0
CHARCOAL PRODUCTION	-2960				-2960	792							0		-2168
STORAGE, DISTRIBUTION LOSSES							-5	-179	-41		-411	-521	-1157	-2107	-3264
FINAL CONSUMPTION	10175	0	0	0	10175	842	623	10613	4506	10096	22425	0	48263	12018	71298
AGRICULTURE AND FISHING											113		113	76	189
INDUSTRY AND CONSTRUCTION											3161		3161	436	3597
TRANSPORTATION								7603	4492		16298		28393		28393
SERVICES							71	640		659	1880		3250	3815	7065
RESIDENTIAL	10175					842	420			9437			9857	5667	26541
FRENCH ARMY							132	2370	14		973		3489	2024	5513
STATISTICAL ADJUSTMENTS															

TABLE 2 ENERGY BALANCE FOR THE FINAL CONSUMPTION OF ENERGY

YEAR: 1985	BIOMASS			HYDROCARBON FUELS								
TEP	Wood	Charcoal	TOTAL BIOMASS	LPG	Gasoline	Jet fuel	Kerosene	Diesel	Fuel oil	TOTAL HYDROCARB.	Electricity	TOTAL
AGRICULTURE AND FISHING								113		113	76	189
INDUSTRY AND CONSTRUCTION								3161		3161	436	3597
TRANSPORTATION					7603	4492		16298		28393		28393
- AIR						4492				4492		4492
- ROAD								6279		6279		6279
- INDIVIDUAL					7475			8147		15622		15622
- RAILWAY								1306		1306		1306
- MARITIME					128			566		694		694
SERVICES				71	640		659	1880		3250	3815	7065
- ADMIN., PUBLIC SERVICES					640		49	1880		2569	1975	4544
- COMMERCE AND BANKS											660	660
- HOTELS, BARS, RESTAURANTS				71			610			681	617	1298
- PUBLIC LIGHTING											155	155
- WATER PUMPING											408	408
RESIDENTIAL	10175	842	11017	420			9437			9857	5667	26541
SUB TOTAL	10175	842	11017	491	8243	4492	10096	21452		44774	9994	65785
FRENCH ARMY				132	2370	14		973		3489	2024	5513
TOTAL	10175	842	11017	623	10613	4506	10096	22425		48263	12018	71298

0.166 TPE. The energy intensity per unit of Gross National Product was 1.18 TPE per million Djibouti Francs (FD).

e) The figures below present the relative weight of each sector in the final consumption of energy.

Agriculture and fishing	0.3 %
Industry and construction	5.0 %
Transportation	39.8 %
Services	17.6 %
Residential	37.3 %

f) The structure of the consumption by energy type is as follows:

Wood and charcoal	15.5 %
Hydrocarbon fuels	67.6 %
Electricity	16.9 %

THE EVOLUTION OF ENERGY DEMAND: THE SCENARIOS

The MEDEE-S model has been used to study two quite distinct scenarios. The results of these simulations are presented in the paragraphs which follow.

The Reference Scenario

This scenario assumes that the social and economic development of Djibouti will continue at the same pace as that seen in the last few years. The GNP is assumed to increase at a rate of 4 % per annum, a rate slightly above the average rate of increase over the last 5 years which was 2.5 %. The industrial and agricultural sectors are assumed to grow at a faster rate than the other economic sectors.

The results of this simulation are presented in Tables 3 and 4.

According to this scenario, which might be termed "Business as Usual", overall energy demand increases by 63 % during the period 1985-2000. The demand for electricity increases by 69 %, petroleum products by 67 %, and biomass by 42 %.

Disaggregating the demand for biomass, one finds that the demand for charcoal is estimated to double, while the final demand for fuelwood increases by 37 %. However, the manufacture of charcoal imposes its own demand on wood, and the demand for wood as primary energy increases by 45 % to about 19,100 TPE by the year 2000.

These estimates emphasize the need to study the forest resource base in Djibouti, to evaluate the extent of deforestation and desertification, and to initiate reforestation programs in those regions which are the worst affected.

Table 3 Reference Scenario - Energy Demand, TPE

	1985 (1)	1990	1995	2000
LPG	623	752	857	990
Kerosene	10096	12752	15786	19739
Gasoline	10613	11137	11738	12223
Diesel fuel	22425	27015	32689	39325
Jet fuel	4506	5537	6737	8196
Sub total	48263	57193	67757	80473
Electricity	12018	14113	16781	20263
Wood	10175	11724	12833	13908
Charcoal	842	1094	1346	1691
Renewable energy	-	-	-	-
TOTAL	71298	84124	98717	116335

1. Energy balance

Table 4 Reference Scenario - Demand by Sector, TPE

Sector	1985 (1)	1990	1995	2000
Industry and construction	3597	4704	6114	7913
Agriculture and fishing	189	240	280	327
Transportation	28393	33009	38621	44888
Services (inc. F.A.)	12578	14047	15912	18168
Residential	26541	32124	37789	45039
TOTAL	71298	84124	98716	116335

(1) Energy balance F.A. = French Army

The demand for kerosene also increases quite sharply in this scenario--almost doubling during the period.

By sector, this scenario shows a very strong increase in energy demand by industry and construction which increases by 120 % during the period. It should also be noted that, by the year 2000, the residential sector takes over from the transportation sector as the largest energy consuming sector.

The Growth Scenario

This scenario assumes that the economy of Djibouti develops strongly, with a rate of growth in the GNP of 5 % annually up to the year 2000.

Industry moves ahead passing from 8.2 % of the GNP in 1985 to 13 % in 2000 ; the energy sector also takes a larger share, while agriculture grows from 4 % to 8.5 % during this period. The service sector declines proportionately going from 76.6 % at the present time to 63.5 % at the end of the period.

This scenario also assumes quite a significant increase in the rate of household electrification. The results of the simulation of this scenario are presented in Tables 5 and 6.

Table 5 Growth Scenario - Energy Demand, TPE

	1985 (1)	1990	1995	2000
LPG	623	916	1379	2346
Kerosene	10096	12867	16795	21893
Gasoline	10613	11758	13270	15815
Diesel fuel	22425	28966	37868	50300
Jet fuel	4506	5809	7414	9462
Sub total	48263	60316	76726	99816
Electricity	12018	14828	19470	26655
Wood	10175	11036	9823	8150
Charcoal	842	1073	1259	1562
Renewable energy	-	449	1726	4391
TOTAL	71298	87702	109004	140574

(1) Energy balance

Table 6 Growth Scenario - Demand by Sector, TPE

	1985(1)	1990	1995	2000
Industry and construction	3597	5007	7063	10247
Agriculture and fishing	189	280	343	430
Transportation	28393	35561	45819	61421
Services (inc. F.A.)	12578	14855	17846	21325
Residential	26541	32000	37932	47052
TOTAL	71298	87703	109003	140575

(1) Energy balance F.A. = French Army

The overall demand for energy under this scenario very nearly doubles during the 15-year period. Disaggregated by energy type, there is a marked increase in the demand for LP Gas, which increases by a factor of more than 3. The demand for kerosene, Diesel fuel, jet fuel, and electricity more than doubles.

The demand for charcoal increases by 86 %, while the final demand for fuelwood actually decreases by 20 % - substituted by kerosene in this scenario. Overall, the demand for wood still increases but only slightly.

By sector, this scenario predictably shows a strong increase in energy demand for the industrial and construction sector, as well as for agriculture and fishing. The consumption of energy by the transportation sector also more than doubles.

Evolution of the Demand for Electricity

Given the importance of electricity in energy supply and hence energy planning in Djibouti, it is essential that the future demand for this particular form of energy be carefully evaluated and assessed.

It should first be recalled that MEDEE-S is a model of final demand, i.e. a model of consumption not of energy production. In order to estimate the production of electricity given the projection of final demand, one must take account of the consumption of electricity which takes place in the power stations themselves, as well as the energy losses which occur in the transmission and distribution system.

During the period 1981-1985 in-house or auxiliary consumption by EdD averaged 7.5 % of production, while transmission and distribution losses accounted for 12.9 % of net production.

Assuming that these numbers decrease slightly in the future, a figure of 18 % has been used to calculate the difference between electricity production and consumption. The evolution of the production of electricity according to the 2 scenarios modelled is shown below in Table 7.

Table 7 Evolution of the Demand and Production of Electricity

	REFERENCE SCENARIO			GROWTH SCENARIO		
	1990	1995	2000	1990	1995	2000
Final demand GWh/an	164.1	195.1	235.6	172.4	226.7	309.9
Production GWh/an (1)	200.1	238.0	287.3	210.3	276.1	378.0
Average annual rate of growth, % (from 1985)	4.0	3.8	3.8	5.1	5.3	5.7

1. Losses and auxiliary consumption taken as 18 % of production.

Taking account of the most recent data on the economic development of Djibouti, as well as the latest figures on the present level of electricity demand, the reference scenario is considered to be the most realistic scenario with regard to the future demand for electricity.

ENERGY SUPPLY: THE OPTIONS

Primary Energy

Renewable energy resources -- solar energy and wind energy -- play only a small role in the supply of energy in Djibouti.

With regard to the supply of petroleum products, it is assumed in this report that these fuel supplies will be available on the world market at least up to the year 2000; the price of these products, however, is obviously very difficult to predict.

It seems unlikely, though, that a serious shortage of petroleum resources will occur over the 15-year planning period covered by this study.

During the same period, the availability of wood for cooking and for the production of charcoal would appear to be sufficient to meet the projected demand--a conclusion, however, that remains to be confirmed by an appropriate study.

Given the above, it may be concluded that it is notably the future supply of and demand for electricity which requires the most detailed study.

Options for the Development of Electricity Supply

The nature of electrical power requires that it be generated in response to the demand, and supplied to the points of consumption via a transmission and distribution network. The supply of electricity therefore depends on the capacity of the generating system to respond at any given moment to the demand imposed by all the consumers linked to the system. Consequently, with regard to electricity supply, it is the total electricity system which must be considered: power stations, and the transmission and distribution system.

The scenarios considered for the future generation of electricity are as follows:

a) Electricity produced by additional Diesel generators.
b) Geothermal power
c) Coal-fired power generation
d) Hydropower generation at Lac Assal.
e) Development of solar power stations.

These options might also be combined in an optimal manner depending on the future development of the electricity system.

It should also be noted that these options do not in any way exclude the generation of electricity in the rural areas of the country by small-scale renewable energy systems such as photovoltaic panels or wind turbines.

These options can be classified in the following manner:

- Those capable of implementation by the year 2000: options a, b and c.
- A backup option for the same period: option c.
- Those options probably impossible to implement before the year 2000: option d (if studies confirm the technical and economic feasibility of such an installation); and option e (if the development of solar energy technologies, both photovoltaic and solar thermal, continues to progress, and if the cost of electricity from these systems becomes competitive with the cost of electricity from the technologies now in operation in Djibouti).

PRINCIPAL ACTIVITIES AND CONCLUSIONS OF THE STUDY

The principal activities and conclusions of the study can be presented as follows :

1. The strategy proposed by the Government for the development of the energy sector has been validated. The aim of this strategy is to assure the supply of energy to the country, and thus its continued socio-economic development.

The reduction of energy imports by the introduction of energy conservation measures, and by the development of Djibouti's national energy resources will lead to a progressive improvement in both the energy situation of the country and its balance of payments.

The major actions proposed are: energy conservation at all steps in the energy system from supply to final end-use; the development of national energy resources -- wood, geothermal energy, wind power, and solar energy; the diversification of energy imports; and the institutional development of the energy-sector agencies and services responsible for policy, planning, management and research.

2. A modern approach to energy planning has been adopted. A methodology specially suited to the elaboration of the national energy balance (presented for 1985) has been applied, together with a sophisticated technique for the analysis of energy demand which has enabled the simulation of the evolution of the demand for energy from 1985 until the year 2000.

The model used for this analysis is the MEDEE-S computer model. This model, only recently devised for the developing countries, has been set up at ISERST and adapted to the specific conditions and the energy situation of Djibouti.

For the decision-makers in the Government agencies responsible for energy policy and planning, the MEDEE-S model is a powerful planning tool. It is imperative that the database used by the model is continually developed and kept up to date.

3. Although the overall energy planning strategy proposed by the Government is validated by this study, the formulation of a comprehensive National Energy Plan has not been possible. The lack of data on certain energy supply options, geothermal energy for instance, means that an economic comparison of the possible energy supply options can not be conducted at the present time. The present situation permits only a general technical and economic comparison of the possible energy alternatives.

In spite of this limitation, it is nevertheless possible to set out the general policy framework of a national energy plan as follows:

- Although the supply of petroleum products on the world market seems assured at least in the short term, it would be useful to study the national system of supply in more detail.

- The energy conservation programs are a priority and should be vigorously promoted and extended.

- The present overcapacity at the Boulaos power station will cover the projected electrical demand until 1992-93. This provides a period of about 3 years before decisions regarding additional capacity need to be taken.

- In a more general manner, the evolution of the overall demand for energy does not require that in the very short term irreversible decisions regarding energy supply need to be taken, since 87 % of the demand is covered by petroleum imports and 13 % by biomass. However, it should be recalled that the construction of new energy supply systems requires very long lead times and these delays should be taken into account.

4. The economic viability of geothermal power in Djibouti has been confirmed.

5. It is recommended that a national energy conservation program be implemented. This program, which would insulate approximately 11,000 refrigerators and which would replace about 15,000 incandescent lights with fluorescent lights, would be financed by a fund accrued by EdD following the fall in the price of oil.

These measures will not only reduce the cost of electricity for the poorer households, but will also reduce the quantity of petroleum products imported and generate a degree of employment.

6. A study of electricity tariffs and a technical and economic assessment of EdD have been conducted. It is proposed that a tariff structure based on long term marginal costs be implemented. However, electricity tariffs should take into account social and political considerations such as the cost of electricity for the poorer households. The precise tariff structure has yet to be determined.

7. Recommendations are made for a series of actions related to energy conservation in the residential sector (thermal insulation, lighting, refrigeration, and cooking), in industry and agriculture, in the transportation sector, and also in the operations of EdD--both technical and economic.

It should also be noted that a number of specific energy development projects have been formulated. These projects will be submitted to the international funding agencies with the aim of securing funds for the financing of the proposed activities.

RECOMMENDATIONS

This study has identified a number of specific measures which are essential for improving energy management and energy planning.

It is recommended that the studies, analyses, and research carried out as part of the preparation of the National Energy Plan should be continued by a full-time group of researchers and analysts. ISERST would appear to be the best place for this activity since the institution would be able to integrate the energy planning work into its current energy research and development programs.

The principal tasks of the new group would be to continue the energy planning work already started; to develop a database of energy and economic statistics and an information centre on energy; to conduct and direct specific studies on issues related to energy; to prepare subsequent National Energy Plans and to improve the analysis and refine the methodology; to prepare specific proposals for consideration by the Government, and to prepare and complete the energy sector development projects to be submitted to the international funding agencies.

For the next few years expatriate technical assistance should be maintained and, if possible, increased.

The National Energy Plan should be revised and updated as more and more information and data on the various supply options become available, if changes in technical and economic variables warrant supplemenatry analyses, or if the analytical techniques themselves change -- for example: the development of a computer model for optimizing the energy supply options.

The recommended actions, activities, and analyses are presented in more detail in the following section.

Energy Management: Final Demand

Residential Sector. Improvements in the thermal insulation of buildings are recommended together with the promotion of energy conservation in lighting, refrigeration, ventilation, and cooking.

Agriculture and Animal Husbandry. Improvements in the efficiency of water pumping is recommended together with the substitution of solar and wind energy for motor pumps fuelled by gasoline and Diesel fuel.

Industry. Energy conservation measures are recommended in industries which are heavy energy users.

Transport. Energy conservation by an improved management of all modes of transportation is recommended.

Energy Management: Secondary Energy

Petroleum Products. A study of the possibility of replacing light fuel oil (600 seconds viscosity) with a heavier grade of fuel oil for the Diesel engine generators at the Boulaos power station is recommended together with a study of the possibility of reducing the consumption of lubricants. An assessment of the overall supply system for petroleum products, including pricing policy, should also be conducted.

Charcoal. It is recommended that the techniques of charcoal production be improved, together with the system of distribution.

Electricity. A study of the possibility of reducing in-house or auxiliary power consumption in the Boulaos power station by changing to an engine cooling system using seawater is recommended. The proposed arrangement may be less costly to operate than the present system which uses air cooling.

A study of the power losses in transformers and in the transmission and distribution system should also be conducted.

A follow-up study of the proposed tariffs designed to improve the management of electricity demand, particularly peak demand, should be carried out. This study should establish a tariff structure which takes into account the socio-economic and political implications of energy prices.

Detailed analyses of the different supply options, geothermal power for example, should be conducted as soon as more precise data becomes available. For the rural areas, technical progress in wind and photovoltaic power should be closely followed, and analyses periodically conducted if the technical and economic characteristics of these options change.

Development of Indigenous Energy Resources

Given the absence of fossil fuel resources in Djibouti, the country should make every effort to develop alternative energy resources even if the significant financial committment which may be required enables only a gradual development of these sources of energy.

Fuelwood. A study of the biomass resource base should be conducted in order to provide a better estimate of the quantities of wood available for fuel and the production of charcoal. Such a study would also permit an evaluation of the possibility of substituting kerosene for fuelwood in the rural areas.

Geothermal Energy. Special attention must be given to the results of the study of geothermal resources which is now in progress. If detailed technical and economic studies show geothermal energy to be feasible and economic, the construction of the first geothermal power station should be undertaken.

Hydropower. Although Djibouti has no permanently flowing streams or rivers, it may be possible to generate hydroelectricity by taking advantage of the fact that Lac Assal is 150 m below sea level. A preliminary analysis might be carried out to ascertain whether or not such a proposal is feasible.

Solar Energy and Wind Energy. The statistical database on wind and solar energy resources is very limited and should be strengthened. These data are important not only for the introduction of solar and wind energy systems in the rural areas of the country, but also for assessing the possibility of building a large solar power plant in the future -- either a photovoltaic system or a solar thermal system using concentrating collectors.

ISERST could help efforts to develop the country's indigenous energy resources : wood, geothermal energy, solar energy and wind power, by setting up an energy database, and in following the technical progress being made elsewhere in the development of technologies exploiting these resources.

Institutional Development

A systematic study of the institutional structure of the energy sector is necessary. This study should define the tasks and the responsibilities of the various agencies and institutions, and should outline a network for the exchange of information.

It is therefore suggested that the members of the team which participated in the preparation of the National Energy Plan should set up a working group, which should include representatives from the Energy Service, the Public Hydrocarbon Establishment (EPH), Electricité de Djibouti (EdD), the Ministry of Public Works and Urban Development (MTPDUL), the Rural Engineering Service (Génie Rural) and the National Meteorological Service, which should examine and discuss ways in which the management of energy supply, production, and demand could be improved, and how the different services, agencies, and institutions should collaborate to achieve this aim. This collaborative effort might be organized under the aegis of the National Energy Commission.

Energy Planning

The National Energy Plan has been prepared with the assistance of the MEDEE-S computer model. In order to extend and improve this computer model at ISERST, a team of at least two analysts should be trained in energy sector planning.

It should also be noted that EdD has agreed to assign an analyst to electrical power planning. This analyst should work closely with the ISERST team.

INTRODUCTION

This introduction to the study of energy planning in the Republic of Djibouti presents the broader context that will serve as a back-drop to the more detailed chapters which follow.

Geographic Position

The Republic of Djibouti is situated on the East coast of Africa between Ethiopia and Somalia at the mouth of the Red Sea and the Gulf of Aden at a latitude of between 11 and 12 degrees North. (Figure 1-1).

Djibouti has a surface area of 23,310 km2 divided into three specific regions : the coastal plain situated 200 m above sea level; the mountains which reach an altitude of 2000 m, and behind the mountains, the plateau where Lac Assal is situated at 150 m below sea level--the lowest point in Africa. /1-1/.

Climate

Djibouti has a tropical climate and is officially classed as a maritime desert : a climatic region that is hot and humid in the winter and very hot and humid in the summer.

In the maritime desert the air temperatures are only slightly less than those of the inland regions. However, the presence of the warm ocean in the area creates a high level of humidity. The temperature of the sea near Djibouti varies from 25°C in winter to 32°C in the summer.

Table A 1-1 in annex A1 gives monthly average temperatures and levels of humidity at the airport in Djibouti based on the effective temperature--a measure of comfort calculated by ombining temperature and humidity /1.2/.

The climate of Djibouti for most of the year is uncomfortable by European standards. Figure A 1-1 in Annex A 1 shows monthly comfort profiles for Djibouti, which vary between 'cool' in the winter and 'intolerable' in the summer.

Rainfall

Annual rainfall in Djibouti is not very high. It varies between 50 and 300 mm per year. Figure A 1-2 of annex 1 shows the level of rainfall and its regional variations /1-3/.

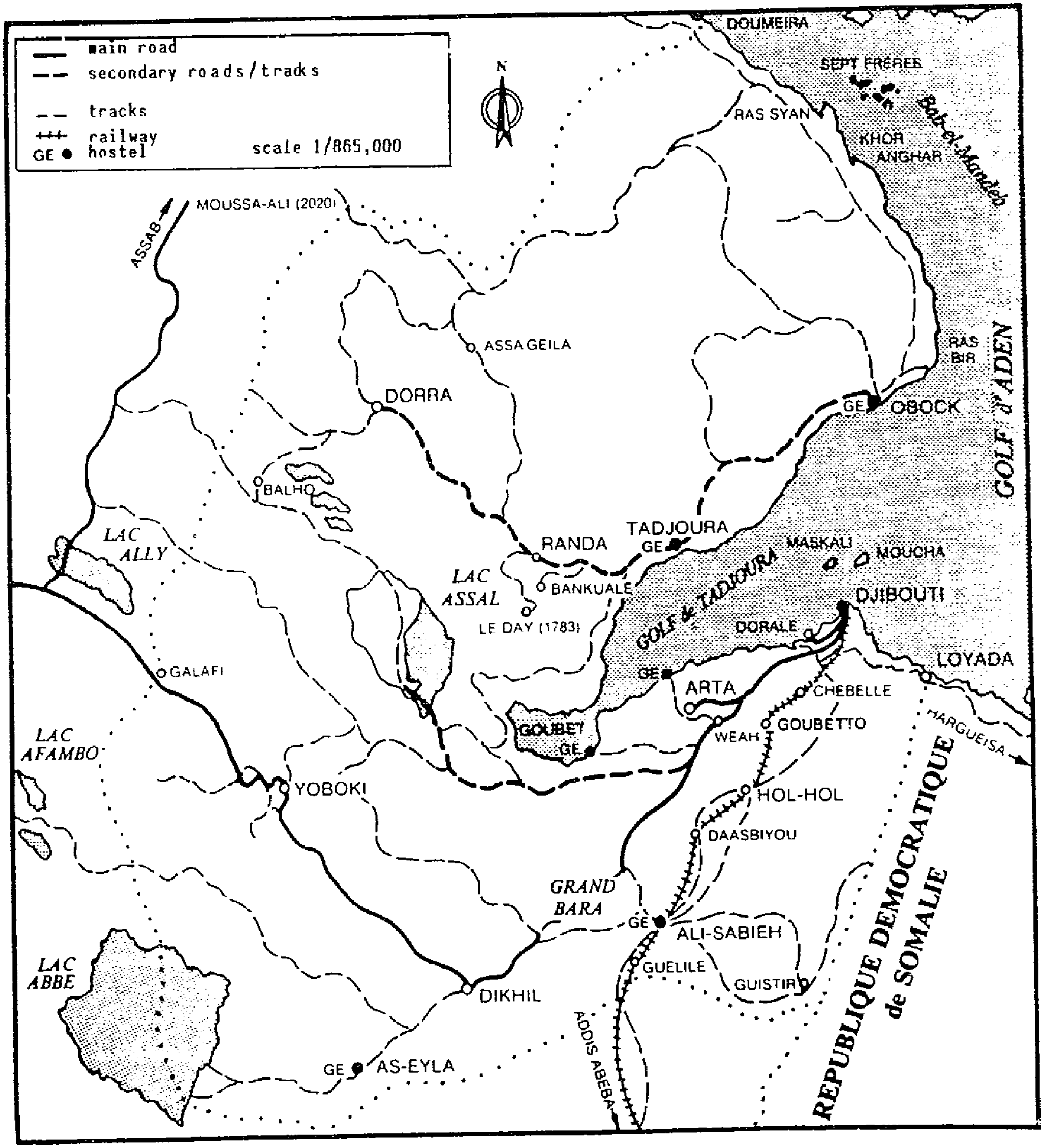

Figure 1-1 Map of Djibouti

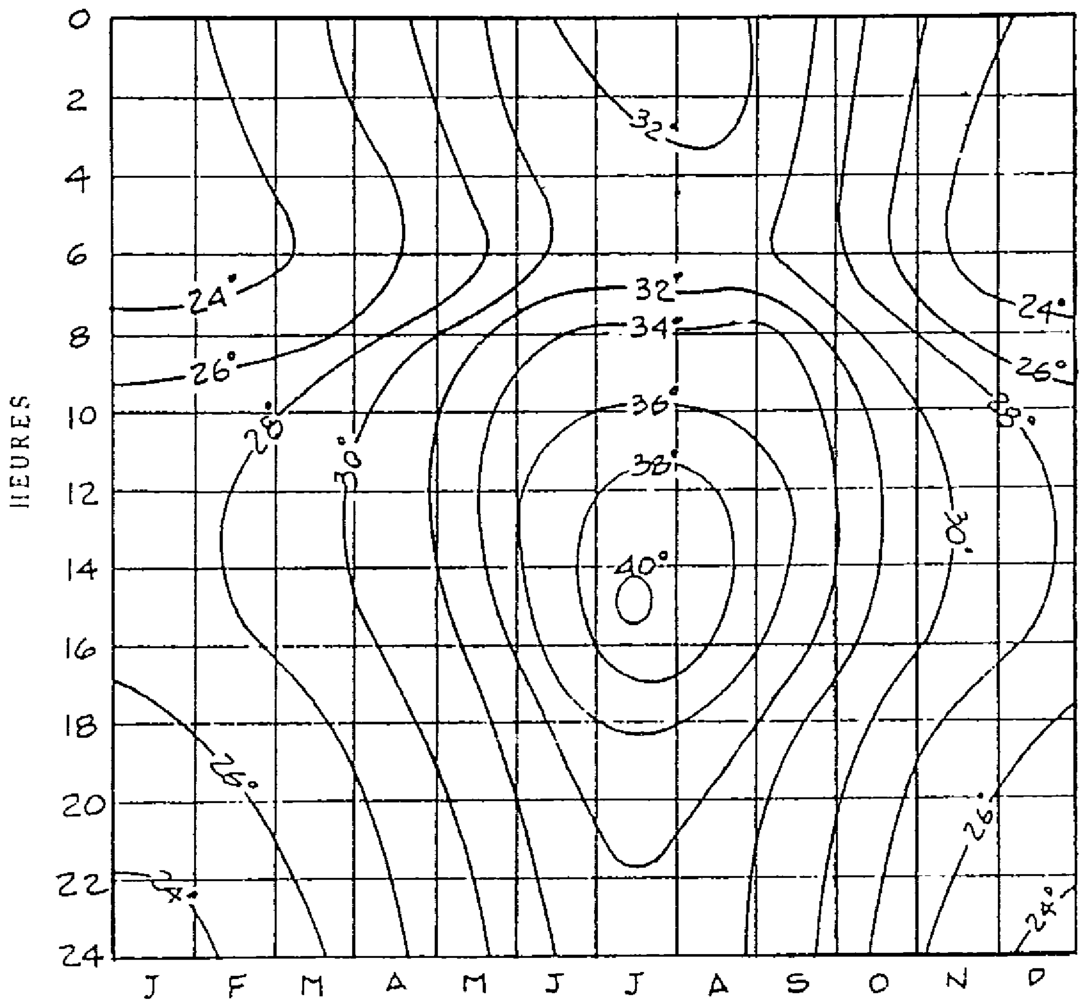

Figure 1-2 Isotherm Chart for Djibouti

Solar radiation

Djibouti's equatorial position, together with its generally clear skies, provide the country with very good solar energy resources. The utilization of solar energy in Djibouti is described in more detail in Chapter 3.

Hydrology

The hydraulic resources of the country consist of both surface and underground water.

The surface water produces two types of hydraulic networks. East of a North-South line passing through Ali Sabieh and Randa, flood waters flow into the sea; whereas in the West the network is more of the endoreic type, i.e. the waters are absorbed in the plains, or in Lac Assal or Lac Abbé, and do not reach the sea /1-4/.

There are no permanently flowing streams or rivers in Djibouti, and none of the wadis maintain a regulated flow. During the periods when the wadis are in flood the volumes of water flowing can be substantial, and the floods often cause serious damage. The floods, which generally last from one to three days, occur 3 or 4 times a year. Most often, they occur in February-March West of the line noted above, and in October-November to the East.

As for underground water , there are many known aquifers-- classified as alluvial aquifers and phreatic aquifers. The alluvial aquifers are supplied by water from the wadis in the North of the country, and in the region between Djibouti and Ali Sabieh by basalt alluvions. However, further to the South the water aquifers are more often sand-ridden.

It is the phreatic aquifers which are most frequently used to supply water. There are two types: the local aquifers and the general phreatic aquifer. The depth of the local aquifers varies between 60 and 180 m, that of the general phreatic aquifer between 0 and 100 m. Figure A 1-3 of annex 1 gives a general picture of the zones and the depth of the local aquifers /1-4/.

Population

Since its independence in 1977 the Republic of Djibouti has experienced a significant increase in population, due not only to an increase in the birth rate (now 3.5% per year), but also to the periodic influx of refugees.

The population increased from 300,000 inhabitants in 1977 to more than 430,000 in 1985. This large increase of approximately 45 % in 8 years has taken place in different ways in different parts of the country, with a noticeably greater increase in the town of Djibouti - the main hub of activity in the country.

The towns in the interior (Ali Sabieh, Dikhil, Tadjourah, Obock), despite a certain amount of migration towards the town of Djibouti, have also seen an increase in their populations. According to a census of August 1986 taken by the National Office of Refugees and the Homeless (ONARS), 13,800 refugees have settled in Dikhil, and 2,322 in Ali Sabieh.

It should be added that Djibouti is home to about 15,000 foreign nationals whose main activities include technical assistance, commerce, and industry -- a large part being the French Army which counts approximately 4,000 men.

Table 1-1 below presents the distribution of the population in 1985.

Table 1-1. Distribution of the Population in Djibouti (1985)

	excl. expatriates excl. refugees	expatriate population	refugee population	total
Djibouti ville	235,000	15,000		250,000
Interior districts:				
urban centres	69,000		15,000	84,000
rural areas	96,000			96,000
TOTAL	400,000	15,000	15,000	430,000

Resources

The known natural resources are limited and consist essentially of salt (Lac Assal), calcium, perlite (from the Geraleyta massif between the Sida plain and the Ghoubet), diatonite (Hanlé, Assal and Gobbad), gypsum (Lac Assal) as well as other minerals which could be useful for the production of cement.

However, the most important resource is geothermal energy--a resource which can be found in many areas of the country. The major resources are at Lac Abbé, Hanlé, Gaggadé, Arta and Lac Assal. Studies are now underway to determine the possibility of fully exploitating these rescurces.

With respect to agriculture, activity is very limited. It is estimated that 320,000 ha of land are irrigable of which only 400 ha are worked at the present time by a thousand or so farmers. Nevertheless, the country has made great progress. National production rose from 50 tonnes in 1979 to almost 1,300 tonnes in 1985.

However, the marketing of the products of livestock farming, agriculture and the fishing industry remains poorly organized, and hinders the development of this sector. As far as livestock is concerned, the situation is becoming increasingly critical.

The free range of livestock combined with frequent droughts over the past ten years has created acute problems of overgrazing in most of the grazing pastures. The result has been a degradation of plant species in the pastures /1-7/.

Although great progress has been made in the fishing industry, the rate of development is held back by the relatively low consumption of sea-food.

Economy

In 1984 Djibouti's Gross Domestic Product (GDP) was 60,450 million Djibouti Francs (FD), almost $375 million (US); 77 % of the GDP is generated by public services: the port, the airport, the Djibouti-Ethiopia railroad, the private banking sector, and general services for the large expatriate population, both civil and military. Agriculture, mostly pastoral, accounts for only 4.4 % of the GDP. Industry accounts for 16 %.

In the case of the Djiboutian economy, there is a significant amount of economic activity which is not included in the GDP. The Gross National Product (GNP) would therefore appear to be a more realistic indicator of the growth of the national economy.

Due to the limited amount of natural resources, and a limited capacity for production, Djibouti is very dependent on imports, especially on food from France and Ethiopia, and on petroleum products. This places a heavy load on the country's balance of trade.

The low level of exports produces a significant imbalance between imports and exports. This situation could be improved by:

- reducing the level of imports, particularly energy imports.
- increasing the level of exports by developing indigenous resources.

For several years the value of the Djibouti franc (FD) has been tied to the US dollar (177.721 FD = $1 US). The absence of any real black market in currency trading is a measure of the ease with which the Djiboutian currency can be exchanged.

The external debt of the country was 44.4 billion FD in fiscal year 1986.

Energy in the Economy

Table 1-2 shows the great importance of imported energy for Djibouti. The figures suggest opportunities for a government which seeks to reduce its commercial deficit by curtailing these imports /1-5,1-6/. The table shows the real expenses incurred by the Djiboutian economy (i.e. excluding taxes, salaries, adjustments etc.) for petroleum products consumed by the country (net petroleum imports).

Table 1-2 shows that expenditures on energy were over 6.2 billion FD ($9.5 million US) in 1982--10.3 % of GDP and 31.6 % of net imports. In the past, the cost of net imports noticeably increased when the price of oil rose.

Since 1986, the substantial fall in the international price of oil has produced a significant positive effect on the balance of payments and the foreign debt of the country.

However, the impact of the importation of petroleum products on the balance of payments will continue to remain important for the country until such times as the substitution of geothermal energy or renewable energy, or the adoption of energy conservation measures, enables the country to reduce these imports.

Moreover, the decentralization inherent in renewable energy resources, as well as the development of geothermal energy, will help to protect the country from possible exterior pressures.

Table 1-2 Energy in the Economy of Djibouti (MFD) /1-5,1-6/

	1979	1980	1981	1982	1983	1984
Gross Domestic Product (GDP)	46,920	53,527	56,818	59,997	59,997	60,234
Total imports CIF (a)	28,436	33,390	36,465	38,381	37,423	37,382
Exports (domestic)	2,047	2,171	3,048	2,400	n.a.	n.a.
Re-exports	12,100	16,500	17,300	18,000	n.a.	n.a.
Total exports FOB	14,147	19,171	20,348	21,200	n.a.	n.a.
Trade balance (total exports - total imports)	-14,289	-14,219	-16,117	-17,181	n.a.	n.a.
Internal market (imports - re-exports)	16,336	16,890	19,165	19,581	n.a.	n.a.
Domestic Energy Economy						
Domestic market	1,754	3,469	3,783	3,737	4,040	n.a.
International market: Imports for aviation	1,303	1,227	1,465	1,552	1,301	n.a.
Imports for shipping and other (b)	370	648	731	898	898	n.a.
Cost of energy for economy	3,427	5,344	5,979	6,187	6,239	n.a.
(Percentage) Energy expenses (c):						
As a percentage of GDP	7.3	9.9	10.5	10.3	10.4	n.a.
As a percentage of net imports	21.0	31.6	30.7	31.6	n.a.	n.a.

(a) Excluding transfers in the free zone; includes products (re-exported products) destined for the French Army, to other non-residents, and neighbouring countries. According to United Nations Conventions, the French Military Base and its personnel (including their families) are in Djibouti to serve the interests of France, and are therefore considered as non-residents; their expenses and their consumption are considered as re-exportation. The technical advisors and other foreigners are considered as residents.

(b) This figure does not include Diesel fuel used in the transportation of imported goods. This fuel is already included in the 'Internal Market' category and is relatively small.

(c) Fire wood and charcoal not included

n.a. : not available

The National Energy Balance in 1985

The national energy balance for a given year presents the overall balance between energy demand and energy supply. The balance shows both the end-use sectors and the different types of energy which satisfy the demand.

The methodology used to develop the national energy balance and the importance of studying its evolution and planning for the future are discussed in more detail in Chapter 2.

At this point, it is appropriate to give a brief overview of the energy situation in Djibouti in 1985 by presenting national energy flows from primary energy resources through secondary conversion to final consumption.

The diagram of energy flows shown in Figure 1-3 is a schematic representation of the national energy situation. These figures are presented in greater detail in tables 2.1 and 2.2 in Chapter 2.

In general, the production of energy is as follows: the national production of primary energy is limited to wood, corresponding to 13,135 TPE (tonnes petroleum equivalent).

With respect to the intermediate or secondary forms of energy, apart from a small quantity of imported charcoal (50 TPE), the principal import is 239,478 TPE of hydrocarbons, of which 154,337 TPE (64.5%) were re-exported. The internal market supply amounted to 99,065 TPE.

Of this quantity, 36,460 TPE (36.8%) was used to generate electricity, 2,960 TPE (3.0%) was used in the production of charcoal, and the remaining 60.2% went directly towards providing final energy for the end-use sectors.

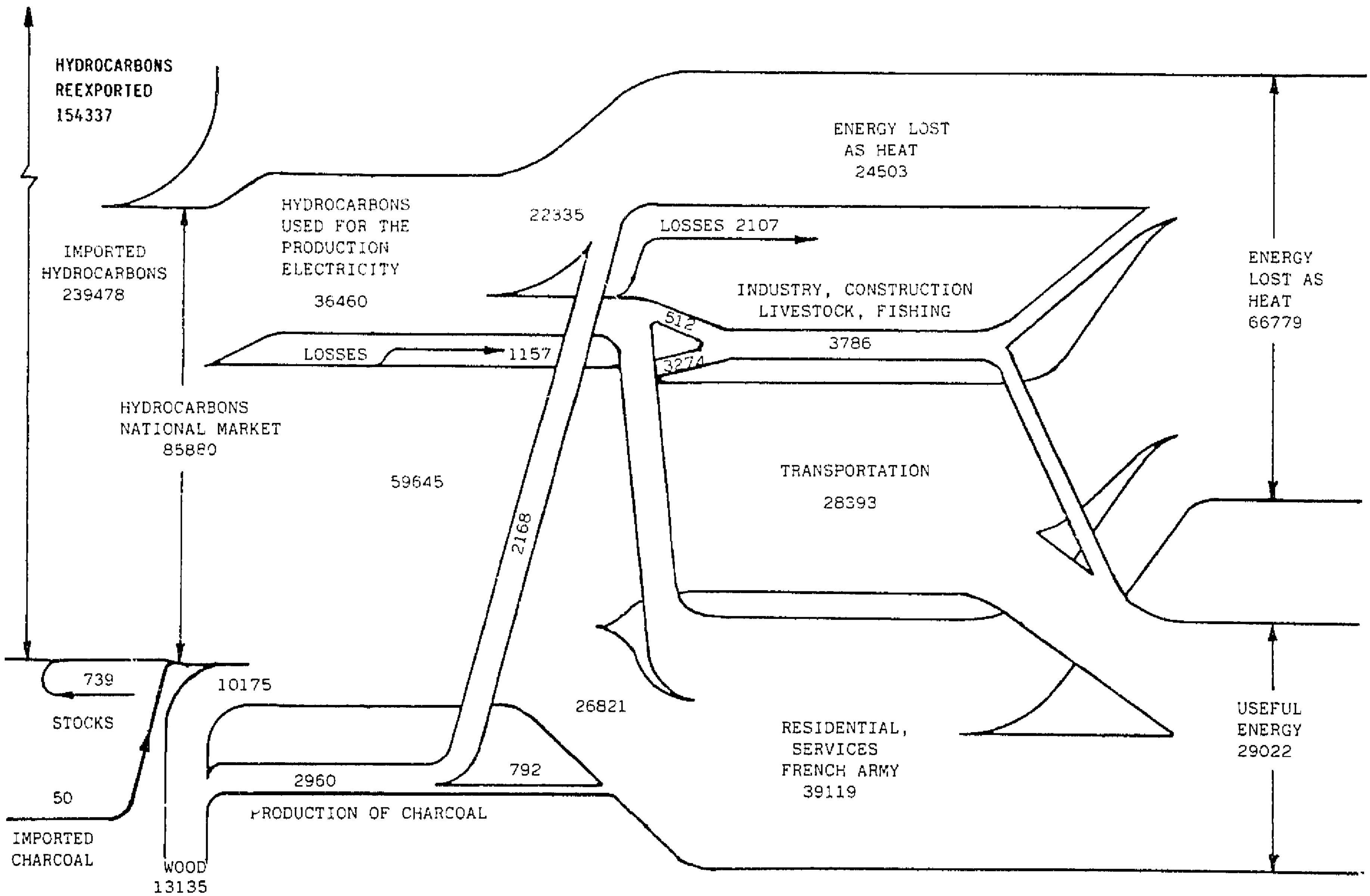

Figure 1-3 The Flow of Energy in the Republic of Djibouti, TPE, 1985.

The consumption of final energy (including electricity) amounted to 71,298 TPE, disaggregated as follows :

Agriculture and fishing	0.3 %
Industry and construction	5
Transport	40
Services	10
Residential	37
French Army	7.7

	100.0 %

The major sectors of final energy consumption are the transport and residential sectors, with 40 % and 37 % respectively. Industry and construction account for only 5 %, below the service sector and the French Army.

Electricity, 16.6 % of final energy, is consumed in decreasing order by the residential sector: 47.2 %, services: 31.7 %, the French Army: 16.8 %, industry: 3.6 %, and agriculture and fishing: 0.7 %.

Apart from the still minimal contribution of solar and wind energy, only 13.1 % of the energy consumed in Djibouti in 1985 was provided by indigenous energy resources: wood; 86.9 % of the energy consumed was imported. It is important that a national energy policy seeks to reduce this heavy dependence on imported energy by developing the geothermal and renewable energy resources of the country as soon as possible.

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ANNEX 1 THE CLIMATE OF DJIBOUTI

Djibouti's climate is officially classed as a maritime desert, a region which has hot and humid climatic conditions in winter, and an extremely hot and humid climate in the summer.

Table A 1-1 shows the levels of temperature and relative humidity, taken every three hours over a 30 year period at the airport of Djibouti /1-2/. These figures, taken two kilometers from the sea can be considered as representative of the temperatures in the town of Djibouti as well as of the areas along the coast in the rest of the country. The table illustrates the characteristics that make Djibout's climate unique: high average temperatures throughout the year, only moderate variations in temperature during the day, and a high level of relative humidity.

Figure 1-2 of the Introduction shows average temperatures over the year.

Figure A 1-1 of this annex shows graphically the relative comfort zones which, determined subjectively, range from 'intolerable' to 'cool'. The diagram shows at what times of day and at what times of year one has to adapt to the exterior climate in order to be comfortable. Air-conditioning systems or ceiling fans are generally used when the effective temperature is in the 3 highest ranges; for the lower ranges, natural ventilation is generally sufficient /1-2/.

Figure A 1-2 shows a rainfall chart for Djibouti /1-3/. Rainfall is very low, and 70 - 100 percent is lost through evaporation and transpiration. Any improvement in comfort lasts only for a few hours -- at most a few days -- and it is quickly followed by an uncomfortable rise in relative humidity as the moisture evaporates.

Table A1-1 Climatic Data Measured at Djibouti Airport /1-2/

Temperature, °C / Relative humidity, %

Heure		Jan	Fév	Mar	Avr	Mai	Juin	Juil	Août	Sep	Oct	Nov	Déc
0:00	T° / HR	23,6 / 79,2	24,2 / 79,0	25,7 / 80.0	27,4 / 79,9	29,5 / 75,5	32,0 / 59,4	32,7 / 45,6	33,3 / 50,6	31,2 / 68,9	27,7 / 76,3	25,1 / 78,1	23,6 / 78,4
3:00	T° / HR	22,7 / 82,3	23,4 / 81,2	25,0 / 81,9	26,5 / 82,7	28,5 / 78,6	31,0 / 60,1	32,0 / 46,6	32,2 / 53,2	30,2 / 71,7	26,8 / 77,8	24,2 / 80,1	22,7 / 81,7
6:00	T° / HR	22,3 / 84,1	23,0 / 82,3	24,4 / 83,3	25,9 / 84,1	27,6 / 80,8	30,0 / 62,1	31,1 / 48,6	31,3 / 54,9	29,6 / 70,6	26,2 / 78,7	23,7 / 81,4	22,3 / 83,3
9:00	T° / HR	25,9 / 71,1	26,3 / 71,1	27,8 / 70,0	30,3 / 68,0	32,6 / 62,7	35,6 / 47,0	35,1 / 37,4	35,8 / 41,5	34,2 / 54,4	30,9 / 63,8	28,6 / 65,6	26,8 / 67,4
12:00	T° / HR	27,7 / 63,7	28,0 / 63,4	29,2 / 64,6	31,0 / 64,9	33,7 / 59,2	37,4 / 44,6	39,6 / 30,8	38,9 / 30,1	36,1 / 48,4	32,3 / 58,4	30,0 / 60,1	28,5 / 60,6
15:00	T° / HR	27,6 / 63,4	28,0 / 64,1	29,1 / 65,3	30,7 / 65,6	33,3 / 61,7	36,5 / 51,8	40,3 / 33,1	39,5 / 35,7	35,5 / 55,6	32,0 / 59,6	29,8 / 61,0	28,3 / 61,2
18:00	T° / HR	25,8 / 70,6	26,2 / 70,7	27,3 / 73,1	29,5 / 73,2	31,5 / 70,1	34,1 / 60,4	36,3 / 46,1	35,4 / 50,7	32,6 / 66,8	29,8 / 67,3	27,6 / 68,2	26,2 / 69,1
21:00	T° / HR	24,7 / 75,6	25,1 / 76,4	26,4 / 77,3	28,1 / 77,1	30,3 / 75,1	32,9 / 62,1	34,5 / 49,7	33,8 / 54,1	31,5 / 71,6	28,5 / 73,6	26,3 / 74,6	25,0 / 74,2
Average daily temp., °C / Average R.H. %		25,0 / 73,8	25,4 / 73,7	26,8 / 74,4	28,6 / 74,8	30,9 / 70,9	33,7 / 55,9	35,7 / 42,2	35,0 / 47,1	32,6 / 62,5	29,3 / 69,1	26,9 / 70,8	25,5 / 72,0
Average min. temperature, °C / Absolute min. temperature, °C		21,7 / 16,8	22,4 / 17,0	23,8 / 16,5	25,5 / 18,5	27,0 / 19,8	29.4 / 24,0	31,2 / 23,3	30,5 / 23,6	29,0 / 23,1	25,7 / 17,2	23,2 / 17,8	21,7 / 16,8
Average max. temperature, °C / Absolute max. temperature, °C		28,5 / 31,0	28,8 / 32,4	30,1 / 36,1	31,8 / 36,3	34,7 / 43,8	38,9 / 45,9	42,1 / 45,8	41,0 / 45,4	37,5 / 44,8	33,0 / 38,2	30,7 / 33,5	29,2 / 32,6
Rainfall, mm		16,8	16,0	26,1	13,1	12,7	0,1	8,5	10,7	4,3	16,7	32,4	8,3

N.B. The average values are based on data collected between 1950 and 1981.

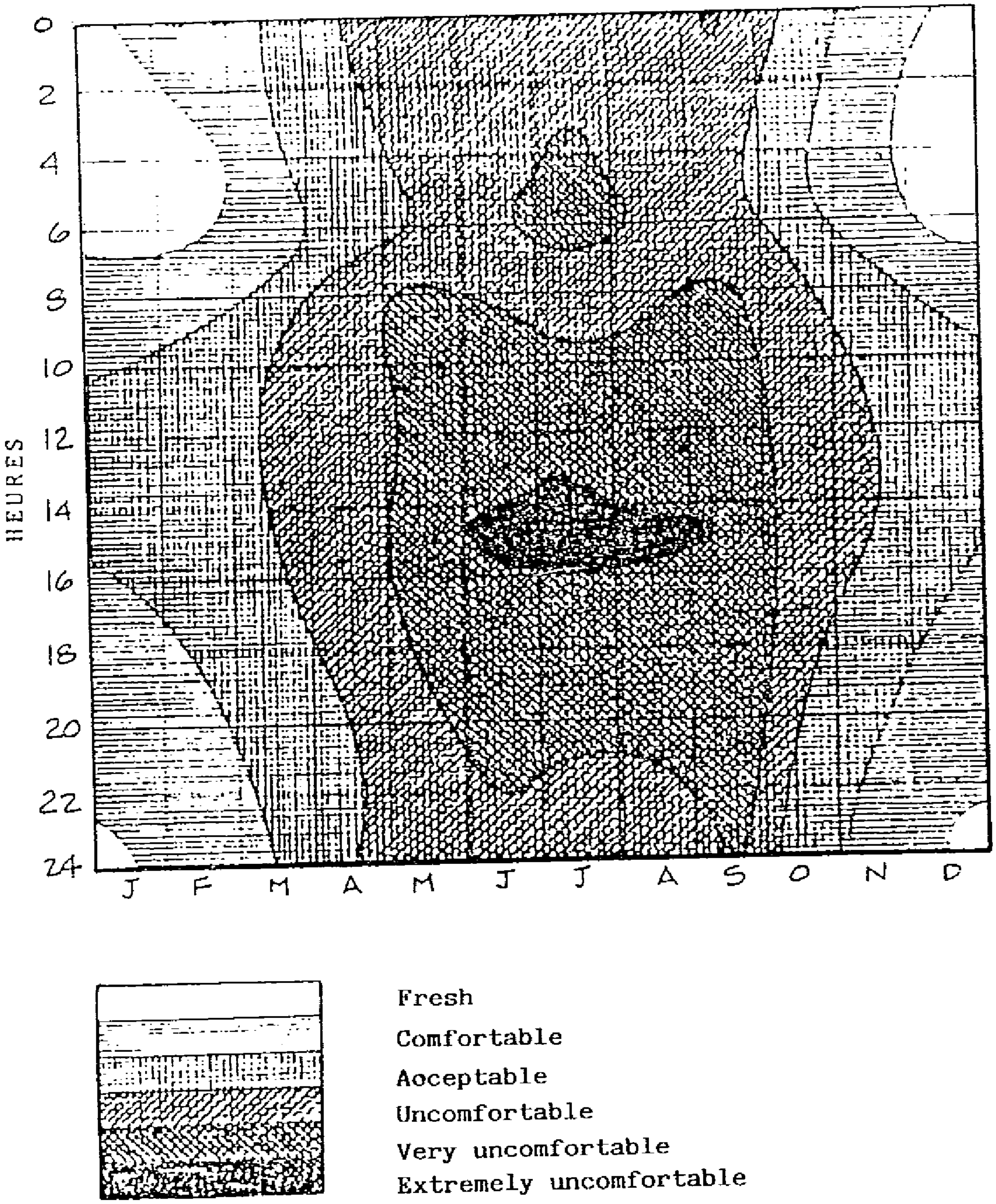

Figure A1-1 Comfort levels in Djibouti

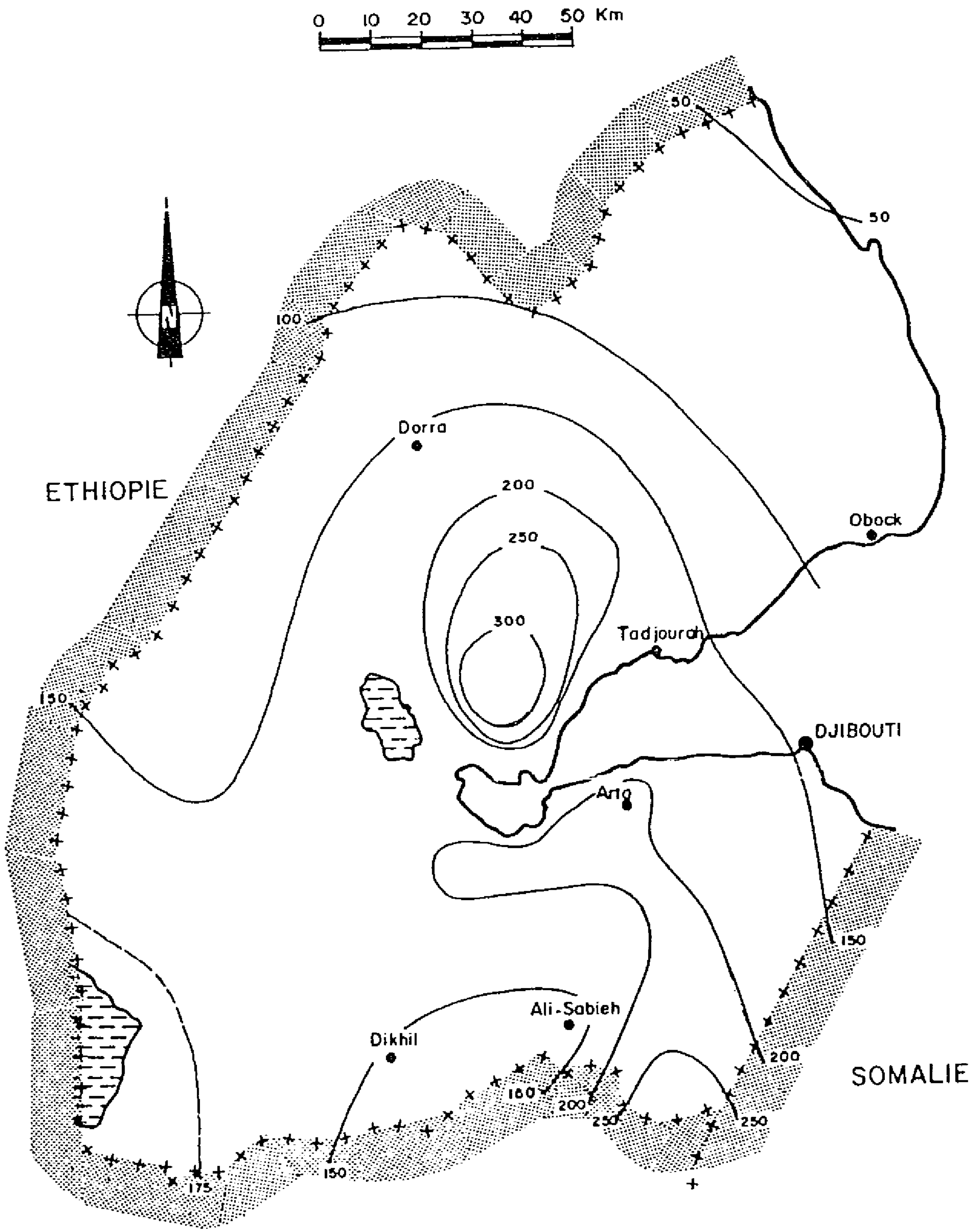

Figure A1-2 Rainfall Chart for Djibouti

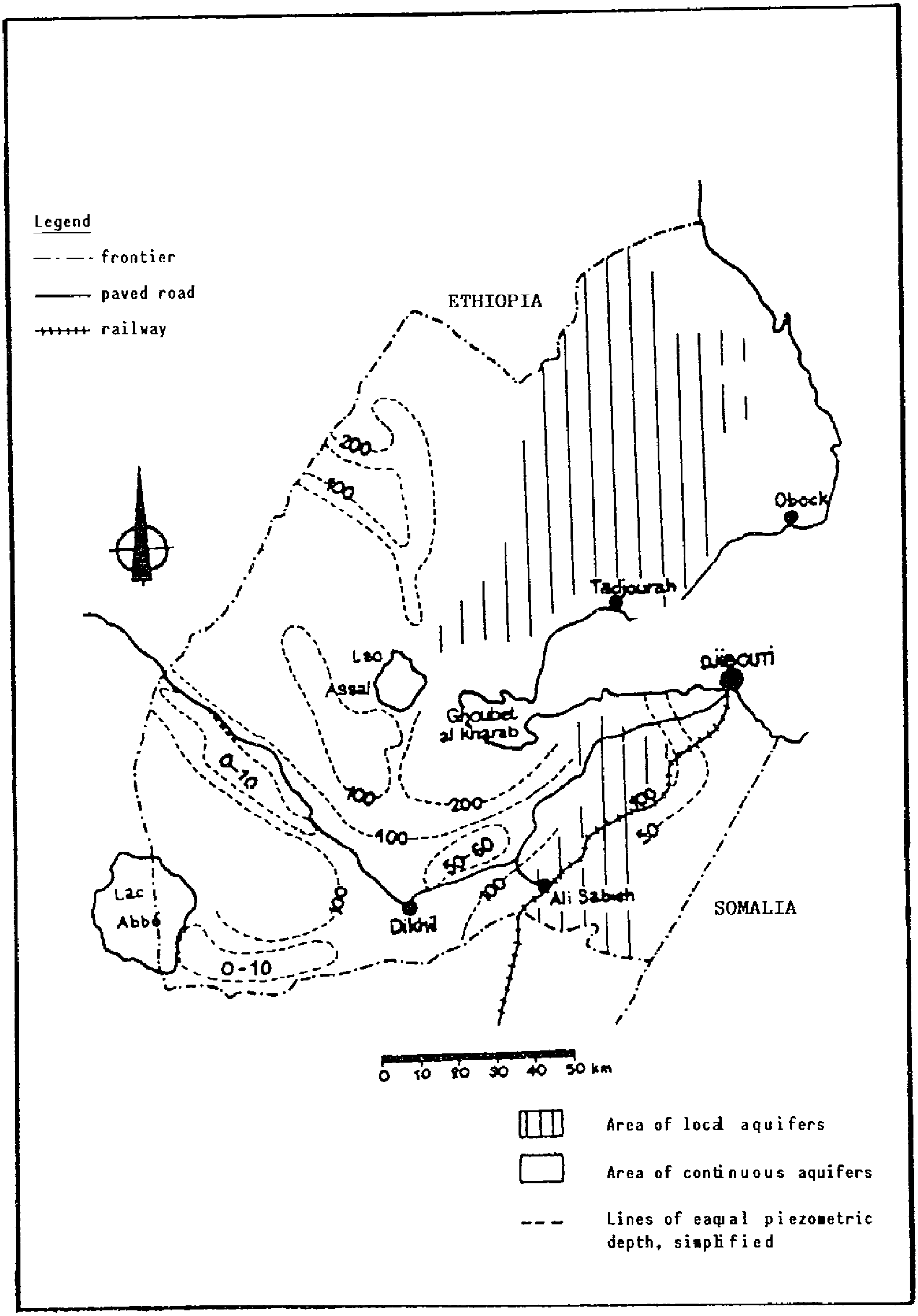

Figure A1-3 Aquifers and their Approximate Depth

CHAPTER 1

ENERGY DEMAND AND CONSUMPTION

Each sector of the economy imposes a demand for different forms of energy. The sum of the various sectoral demands constitutes the country's total energy demand.

This chapter presents an inventory of the sectors which are part of the national economy, discusses their principal characteristics, and provides an analysis of sectoral energy demand.

1.1. RESIDENTIAL AND SERVICE SECTORS

1.1.1. The Residential Sector

Although the lifestyle of the population varies considerably from one district to another and within the districts themselves, the population can be broadly disaggregated into 3 principal groups in terms of lifestyle and patterns of energy consumption. These groups are defined geographically as Djibouti ville, the District centres and the larger towns, and the village and rural populations.

The characteristics of each of these groups are described in the sections which follow.

1.1.1.1. Djibouti ville

The authors of the urban development master plan /1.1/ described living conditions in Djibouti ville in 1983 as follows:

> "The distribution of the population in the capital city, its structure, and its various levels of density indicate different types of urban groups, each having its own specific customs. Socio-economic segregation is very apparent and divides the city into two very distinct parts :
>
> - Residential sectors well-equipped, sparsely populated, airy, green and clean resulting from planned, controlled management.
>
> - Residential sectors under-equipped, densely populated and cramped which are the result of spontaneous urban growth."

These zones, or quartiers, generally contain uniform social groups with well defined patterns of energy consumption.

The survey carried out during 1986 for the National Directorate of Statistics (DINAS, annex 1.2) on household energy consumption made it possible to obtain the different elements necessary to evaluate the residential sector : type of dwelling (building material, number of rooms, etc.), water, electricity, number and type of home appliances, energy bills, etc.

This analysis showed that the number and type of electrical appliances in use, and particularly the presence or absence of air conditioning units, presented the most accurate criterion for differentiating among socio-economic groups

Four principal household types were thus defined within the population of Djibouti ville : low-income families, those with middle level incomes, those in the higher income bracket, and finally expatriate households.

It should be noted that the household is the unit employed for the estimation of energy consumption. The average number of persons in the household is taken as 7.5.

However, the definition of low, middle and high income households is related more to the pattern of energy consumption than to actual income. For instance there may well be high-income households with low-income patterns of energy consumption, and vice versa.

a-1) Low Income Households

This category groups all of the households which do not have access to air conditioning--close to 71.8% of the total number of households. However, they may have access to electric power for other uses. Their dwellings are rarely made of cement blocks, but are more generally constructed of materials such as wooden board, plywood, and sheetmetal, which provide for only minimal interior comfort.

When these households have access to electricity, either by direct connection to EdD, or by pirating it off a neighbour's meter, they will generally use it for two or three lights (most of them fluorescent), a fan in the main room, and possibly a refrigerator or a television set.

Cooking is done traditionally using kerosene stoves. The central zones of the city (quartiers 1 through 7) contain the majority of these households.

When households do not have access to electricity (mainly in Balbala), they use kerosene, and less frequently wood, for their energy needs -- cooking and lighting. At least 12,000 households are in this category, which constitues too large a figure to be ignored. It should be noted, however, that this number will significantly decrease over the short and mid term due to urban development projects which are already in progress.

Table 1.1.1. is based on the survey undertaken by the DINAS and shows the number and type of appliances found in the low income households.

Table 1.1.1 Appliances in Low Income Households

	number of low income households	Lighting incandescent bulbs	Lighting fluorescent lights	fans	air conditioners	refrigerators	tele-visions
number of households using the appliance	23,056	12,361		11,528	0	8,056	5,556
% of low income households		53.6 %		50 %	0 %	34.9 %	24 %
average number of appliances		1.08	1.9	1.5	0	1	1

a-2) <u>Middle Income Households</u>

This category includes all households owning an air-conditioner--one only. This group accounts for 16.5% of total households.

These dwellings, concentrated in clusters or residential areas in well defined zones, are made of concrete blocks, in contrast to the light construction of low income homes.

In addition to the air conditioning unit, which is used only during the worst heat of the summer when the high temperatures (45° Centigrade) and the hot khamsin wind cause great discomfort, these households also frequently own a refrigerator, a television, at least four lights (the majority of which are incandescent) as well as two or three fans.

With the exception of a few families who use a gas stove, cooking is done on kerosene stoves.

Table 1.1.2 gives a more precise breakdown of the type and number of electrical appliances in use by these households.

Table 1.1.2 Appliances in Middle Income Households

	number of middle income households	lighting		fans	air conditioners	refrigerators	tele-visions
		incandescent	fluorescent				
number of households using the appliance	5,278	5,278		5,000	5,278	4,792	4,653
% of middle income households		100 %		95 %	100 %	90.8 %	88 %
average number of appliancess		1.42	3.08	2.54	1	1	1

a-3) <u>High Income Households</u>

This category groups the households (excluding expatriates) who own more than one air conditioner. The group accounts for a relatively low percentage of total households -- 5.2 %.

The houses, which are located in the city's most affluent neighbourhoods (Plateau du Serpent, le Heron, le Marabout, etc.), are made of concrete and provide a high level of comfort.

These households own a refrigerator, one or more television sets, ten or so lights, as well as ceiling and wall fans. Cooking is done on gas stoves or on kerosene stoves, depending on what type of meal is being prepared.

The distribution of electrical appliances in these households is given in Table 1.1.3.

Table 1.1.3 Appliances in High Income Households

	number of high income house-holds	lighting: incandescent bulbs	lighting: fluorescent lights	fans	air-conditioners	refrigerators	tele-visions
number of households using the appliance	1,666	1,666		1,666	1,666	1,666	1,666
% of high income households		100 %		100 %	100 %	100 %	100 %
average number of appliances		4.8	4.0	3.7	2.45	1	1

a-4) Expatriate Households

The total number of expatriates in Djibouti (visiting consultants, merchants, industrialists, military personnel) is estimated at about 15,000, which represents approximately 2,000 households or 6.5% of the total. Average family size is much lower than the Djiboutian average.

In addition, a significant part of this group does not belong to traditional households. This segment is made up principally of the military personnel in the different regiments of the French armed forces. From a statistical viewpoint, they are accounted for in the category of collective households.

The location of these expatriate dwellings is similar to that of high income local families. However, there are certain areas near the regiments and the air base where these households predominate.

The houses are extremely comfortable, and all have several air conditioning units. Cooking is done on butane stoves--rarely on electric stoves.

The number and type of electrical appliances owned by this category is comparable to those owned by high-income local families shown in Table 1.1.3.

b) The Different Uses of Energy

b-1) Lighting

The assumptions used in calculating electricity consumption for lighting are given below :

- average power of incandescent bulbs	60 W
- average power of fluorescent tubes	30 W
- daily use (cooler season)	
- low and middle income households	3 h
- high income and expatriate households	3.5 h
- daily use (hot season)	
- low and middle income households	2.5 h
- high income and expatriate households	3 h

Taking into consideration both the number of appliances in use and the time of use, energy consumption for lighting purposes reaches 4,232 MWh, distributed as indicated in Table 1.1.4.

Table 1.1.4 Electricity Consumption for Lighting in the Residential Sector

Household group	number of house-holds	number of households with lighting	monthly consumption per household (kWh) cool season	monthly consumption per household (kWh) hot season	Annual consumption per household (kWh)	Annual consumption total (MWh)
low income	23,056	12,361	10.9	9.1	122.6	1,516
middle income	5,278	5,278	16.0	13.3	178.8	944
high income	1,666	1,666	42.8	36.7	483.2	805
expatriate	2,000	2,000	42.8	36.7	483.2	967
Total residential sector						4232

b-2) <u>Ventilation</u>

Basis for calculating consumption :

Average power per fan 80 W

Average Daily Use : (cool season)
Low income households 7 h
Middle income households 6 h
High income households and expatriates 6 h

Average Daily Use : (hot season)
Low income households 7 h
Middle income households 4 h
High income households and expatriates 3 h

Table 1.1.5 gives the consumption of electricity for ventilation by type of households.

Table 1.1.5 Consumption of Electricity for Ventilation in the Residential Sector

Household group	number of households	number of households with fans	Monthly consumption per household (kWh) cool season	Monthly consumption per household (kWh) hot season	Annual consumption per household (kWh)	total (MWh)
low income	23,056	11,528	25.2	25.2	302	3,486
middle income	5,278	5,000	36.6	36.6	378	1,890
high income	1,666	1,666	53.3	26.6	506	843
expatriate	2,000	2,000	53.3	26.6	506	1,013
total						7,232

b-3) Air Conditioning

Basis for calculating consumption :

Average power per unit 1400 W

Average Daily Use : (cool season)

Middle income households 0 h
High income households and expatriates 3 h

Average Daily Use : (hot season)

Middle income families 10 h
High income households and expatriates 10 h

Table 1.1.6 gives a breakdown of residential air conditioning consumption by household type.

Table 1.1.6 Consumption of Electricity for Air-Conditioning in the Residential Sector

household group	number of house-holds	number of households with air conditioners	Monthly consumption per household (kWh) cool season	Monthly consumption per household (kWh) hot season	Annual consumption per household (kWh)	Annual consumption Total (MWh)
low income	23056	0	0	0	0	0
middle income	5278	5278	0	336	1677	8853
high income	1666	1666	206	823	5556	9257
expatriate	2000	2000	206	823	5556	11112
total sector						29222

b-4) <u>Refrigeration</u>

Basis for calculating consumption :

Average monthly consumption per refrigerator
(Ambient temperature 25°C)

Small model (140 l)	40 kWh
Large model (220 l)	50 kWh
Large model with freezer (300 l)	60 kWh

Average monthly consumption per refrigerator
(Ambient temperature 28.5 °C)

Small model (140 l)	50 kWh
Large model (220 l)	75 kWh
Large model with freezer (300 l)	90 kWh

Average Monthly Consumption per Refrigerator
(Ambient temperature 39° C)

Small model (140 l)	120 kWh
Large model (220 l)	140 kWh
Large model with freezer (300 l)	180 kWh

These values are taken from readings of the curve in "Equipment 1983 " published by ASHRAE /1.2/.

Table 1.1.7 gives the distribution of electricity consumption for residential refrigeration according to household groups.

It should be noted that the monthly consumption rates do not correspond to those of any particular refrigerator model but are based on information collected during the DINAS survey.

Table 1.1.7 Electrical Consumption for Refrigeration in the Residential Sector

household group	number of house-holds	number of households with refrigerators	monthly consumption per household (kWh)		annual consumption	
			cool season	hot season	by household (kWh)	Total (MWh)
low income	23056	8056	67	132	1129	9095
middle income	5278	4792	60	122	1030	4935
high income	1666	1666	56	103	906	1511
expatriate	2000	2000	56	84	812	1624
Total sector						17165

b-5) <u>Other Domestic Uses of Electricity</u>

Under this heading are grouped the other domestic energy uses which have not been considered above: television, radio and small appliances.

The estimation of electricity consumption is based on the number of television and radios in use, and on the average listening time.

Basis for calculations:

Average power of a radio/TV set :

Small model	80 W
Average model	125 W
Large model	150 W

Average listening time varies from 3 to 5 hours depending on the household.

Table 1.1.8 Electricity Consumption for Television, Radio, and Miscellaneous Appliances

household group	number of households	number of households with radio, television, miscellaneous	monthly consumption per household (kWh)		annual consumption	
			cool season	hot season	by household (kWh)	Total (MWh)
low income	23056	5556	7	7	86	480
middle income	5278	4653	15	15	180	838
high income	1666	1666	22	22	270	450
expatriate	2000	2000	22	22	270	540
Total						2308

b-6) Electricity Demand Balance

Tables 1.1.9 a, b, and c give the final distribution of the demand by type of household and category of use for 1985, one month of the cool season, and one month of the hot season respectively.

Table 1.1.9 (a) Annual Consumption of Electricity by Category of Household and by Use, 1985

use: household	lighting	ventilation	air conditioning	refrigeration	other uses	Total (kWh)
low income	122	302	0	1129	86	1639
middle income	178	378	1677	1030	180	3443
high income	483	506	5556	906	270	7721
expatriate	483	506	5556	812	270	7627

Table 1.1.9 (b) Monthly Consumption of Electricity in the Cool Season by Category of Household and by Use (kWh)

use: Household	lighting	ventilation	air conditioning	refrigeration	other uses	total kWh
low income	10.9	25.2	0	67	7	110.1
middle income	16.0	36.6	0	60	15	127.6
high income	42.8	53.3	206	56	22	380.1
expatriate	42.8	53.3	206	56	22	380.1

Tables 1.1.9 b and 1.1.9 c show the evolution of electricity demand by household type during the course of a typical year. This information should be taken into account when EdD's electricity tariffs are revised.

This evolution is presented schematically in Figure 1.1.1 and shows a ratio of 1.6 between consumption during the hot and cool seasons for low income families; this ratio is 4.1 for midddle income families and 2.6 for the higher income households.

Table 1.1.9 (c) Monthly Consumption of Electricity in the Hot Season by Category of Household and by Use (kWh)

use: Household	lighting	ventilation	air conditioning	refrigeration	other uses	total kWh
low income	9.1	25.2	0	132	7	173.3
middle income	13.3	36.6	336	122	15	522.9
high income	36.7	26.6	823	103	22	1011.3
expatriate	36.7	26.6	823	84	22	992.3

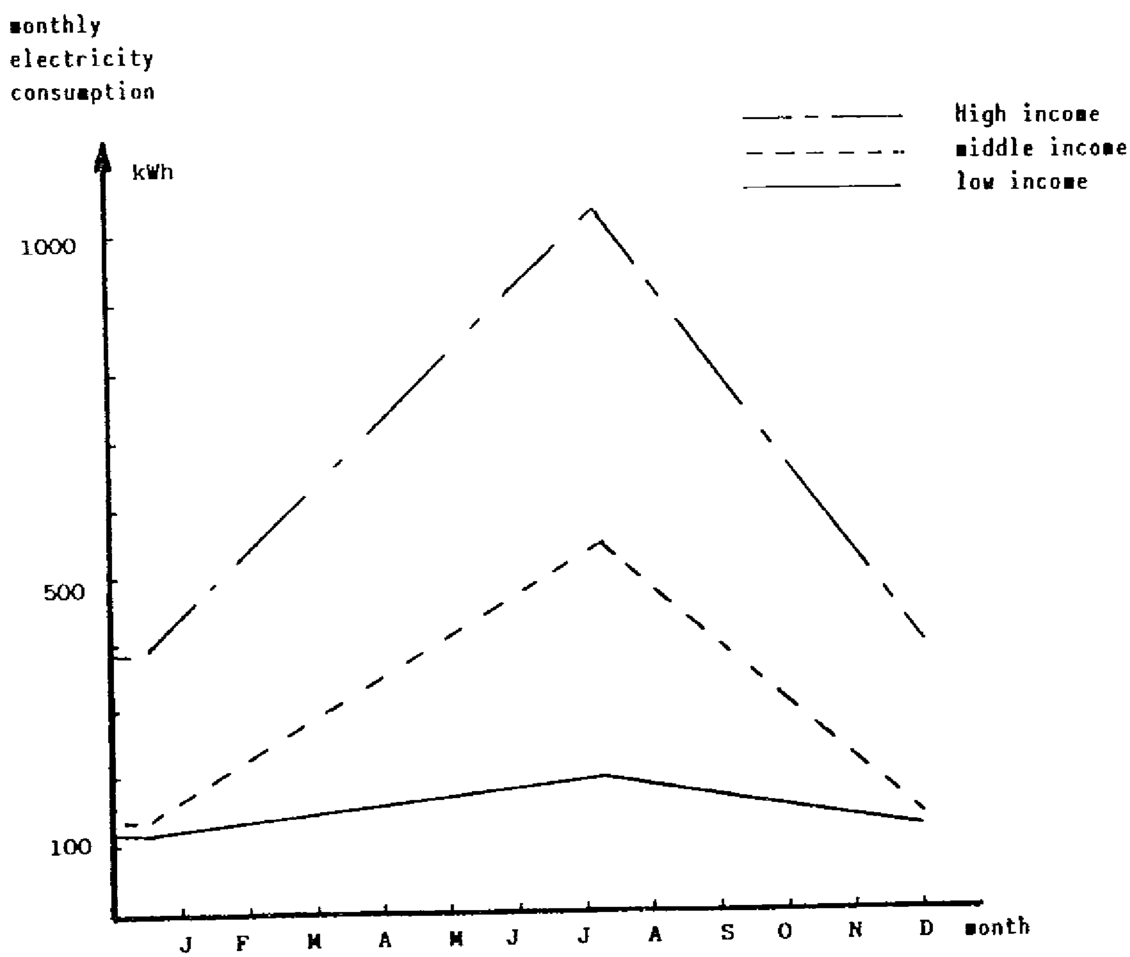

Figure 1.1.1 Annual Variation in Household Demand for Electricity

The final balance for the entire residential sector of Djibouti ville is shown in Table 1.1.10. The total demand for electricity reached approximately 60,000 MWh in 1985.

Table 1.1.10 Demand for Electricity by the Residential Sector of Djibouti ville, 1985

use: Household	lighting	ventilation	air conditioning	refrigeration	other uses	Total MWh
low incomes	1516	3486	0	9095	480	14 577
middle income	944	1890	8853	4935	838	17 460
high income	805	843	9257	1511	450	12 866
expatriate	967	1013	11112	1624	540	15 256
Total (MWh)	4232	7232	29222	17165	2308	60 159

In conclusion, this table shows that 50% of the electricity consumption by the residential sector can be attributed to air conditioning, 28% to refrigeration, 12% to ventilation, 7% to lighting and 3% for other purposes.

Regarding energy conservation policy, it is clear that initiatives should focus on air conditioning and refrigeration. These activities should highlight bioclimatic or energy efficient building design with thermal insulation where appropriate, as well as the thermal insulation of refrigerators. These aspects will be dealt with later in this study.

Note: Although the towns of Arta and Oueah are not a part of Djibouti ville, they are an integral part of the District of Djibouti and they receive their electric power from the generating stations in Djibouti ville. Their electricity consumption shows certain differences in comparison with that found in Djibouti ville and in the District centres. This is due in part to the climatological conditions affecting Arta--its altitude significantly reduces temperatures--and also to the type of electricity consumers: weekend and summer visitors, military families, etc.

A quick survey taken by ISERST of 25 households in Arta identified the type of energy used for the principal end-uses, and also provided an idea of the average number and type of appliances in use.

However, the survey did not permit any precise definition of average consumption by household type, particularly for those households only intermittently present at weekends, or in the summer, etc.

The estimate based on the information collected indicates a demand of approximately 1600 kWh, or 137 TOE.

Cooking

In Djibouti ville, households use four different methods of cooking :

- wood fire: the peripheral population as well as a portion of the households in Balbala.
- kerosene stove: low and middle income families.
- gas stove: upper income families (often together with a kerosene stove), and expatriates.
- electric stove: the very few in use are employed in a number of expatriate and upper income households.

Wood

In addition to the daily preparation of food, there are particular cooking traditions which entail specific energy consumption: feasts and ceremonies, for example, are occasions when large amounts of wood will be consumed (35 kg/year per family according to the report by Dominique Briane) /1.3/.

Apart from such occasional use, a number of households in Balbala and in the areas surrounding Djibouti ville use wood for cooking. Briane estimated that 1,200 households fall into this category with an annual consumption of about 1,700 kg.

The number of these households is declining steadily because wood is costly and not always available, whereas kerosene is subsidized by the Government and is widely distributed.

Charcoal

Only a very few households use charcoal for cooking. Charcoal is more frequently used by expatriate households for "Bar-B-Ques", and by other types of households for a variety of purposes : religious rites, to repel mosquitoes, etc .

Average consumption per household was estimated by Briane at 29.6 kg/year. Consumption varies according to the season. Greater quantities are used during the rainy season from November to February.

Kerosene

Daily kerosene consumption was checked during the DINAS survey. The survey showed that the average household consumes approximately 1.03 liters of kerosene per day, or 140 ml/person/day. This rate of consumption may vary even though foods use daily remained more or less the same: rice, or boiled pasta with meatballs and sauce.

LPG

The Shell Oil Petroleum Company has a monopoly on the distribution of LPG in Djibouti. In 1985, it sold 628 TPE of LPG, of which 132 TPE were sold to the French Army, 71 TPE to the service sector and 420 TPE to the residential sector.

According to the DINAS survey and other calculations, it was found that the average expatriate household consumes 70 kg of LPG per year, whereas a local household in the middle or upper income range consumes 176 kg per year. This difference is due both to the different styles of cooking--the local cuisine requiring more preparation and being cooked for a longer period--and the fact that expatriate households are smaller.

It should be noted that many households also use a kerosene burner as well as an LPG stove. The kerosene stove is used for the preparation of certain traditional dishes.

Electricity

The use of electric stoves is not common. The impact of this mode of cooking on energy demand is negligible.

Recapitulation

Table 1.1.11 provides a synthesis of cooking habits as well as an estimate of individual and total annual consumption for each energy type.

Table 1.1.11 Energy Consumption for Cooking in Djibouti ville

	Household group	Use	Annual consumption per household	Annual consumption	
				Total	TPE
Wood	Low income households on the outskirts	cooking	1700 kg	2000 T	740
	All households except expatriates	ceremonies fêtes	35 kg	1300 T	480
Charcoal	All households except expatriates	religious rites mosquito repellent	29.6 kg	996 T	670
	Expatriates	barbecues grills	52 kg	130 T	90
Kerosene	All households except expatriates	cooking	375 l	10231 m3	8160
LPG	High income households	cooking	176 kg	252 T	259
	Expatriates	cooking	70 kg	145 T	149
Electricity	A few high income households and expatriates	cooking		negligible	
TOTAL					10548

1.1.1.2. The Districts

a) Electricity Demand - Qualitative Analysis

The first important difference which appears in the pattern of energy consumption between the households in Djibouti ville and those in the Districts is the marked reduction in the electricity demand of households in the Districts.

Based on the number of subscribers and the amount of electricity sold in 1985 (although the official figures of EdD do not account for fraudulent use or parallel hookups), annual average consumption per low-voltage subscriber is approximately 4,000 kWh in Djibouti ville, while it is only 2,200 kWh in the interior, i.e. there is a ratio of almost 2 to 1 between the two levels of consumption.

To determine the reason for these differences, ISERST conducted a survey during the third quarter of 1986 of household energy consumption in the Districts.

This survey was conducted in Arta, Ali Sabieh, Dikhil, Tadjourah, Obock and in the region of Hol Hol. In each town the interviewers contacted 50 households which were representative of the local population.

The analysis of the responses clearly show that the main reason for the difference in household electricity consumption between Djibouti ville and the other towns is because the percentage of the population using air conditioners is much lower in the Districts.

There are a number of reasons why air conditioning is less prevalent in the Districts: the climate is different, family incomes are lower, and there are very few expatriate families.

Table 1.1.12 summarises the results of this survey and shows the number of households with electricity, as well as the type of appliances being used.

Table 1.1.12 Electricity Consumption in the District Centres

	number of households(a)		Number of households possessing:				households
	with electricity	without electricity	electric lights(d)	refrigerators	fans	air conditioners	with electricity (c)
Ali Sabieh (b)	29	13	29	22	23	8	63 %
Dikhil (b)	20	17	20	13	20	6	58 %
Tadjourah	37	12	37	32	34	19	69 %
Obock	38	11	38	31	31	17	68 %

Notes

a) The survey was based on 50 households in each town, but certain responses have not been included.

b) The percentage of households with electricity is in fact much lower if one takes account of the refugee populations. This is particularly true of Dikhil where there are about 15,000 refugees without electricity.

c) This value is based on the weighted mean of the results from each quartier. The figures are generally higher than the number of registered subscribers because of parallel hookups, etc.

d) Fluorescent lights are generally used for lighting.

b) Electricity Demand: Quantitative Analysis

The data available on electricity sales to the residential sector are few, and are often open to interpretation. For example, the figures do not allow one to precisely estimate the demand at each District centre.

Noting the above, Table 1.1.13 presents an approximate profile of electricity demand for each of the District centres.

Table 1.1.13 Estimation of the Residential Demand for Electricity in the District Centres

	low voltage subscribers public	private	Total annual production MWh	Estimated demand MWh	Average demand per household kWh/year
Ali Sabieh	74	382	911	800	1400
Dikhil	74	291	1190	1000	2000
Tadjourah	86	317	2677	1800	3500
Obock	44	168	640	550	1500
TOTAL	278	1158	5418	4150	

Note: Household electricity consumption in Tadjourah is markedly higher than the other towns. This characteristic appears to be due to a more widespread use of air conditioning.

Bearing in mind the remarks above, these figures suggest that the total demand in the Districts only reaches a little over 4,000 MWh, or about 6% of national electricity consumption in the residential sector.

These figures emphasize the need for a detailed analysis of household energy consumption in Djibouti ville so that this demand sector can be accurately modeled.

c) Cooking : Qualitative Analysis

The survey undertaken by ISERST in the Districts also examined the use of different fuels for cooking. Table 1.1.14, taken from Dominique Briane's report, gives a breakdown of the number of households by type of energy used for cooking /1.3/.

Table 1.1.14 Fuels Used For Cooking in Different Districts

	Number of families surveyed	families cooking only with wood,%	families using both wood and kerosene %	families generally using kerosene %	average number of persons per family	For the families cooking with kerosene: consumption per family, litres/day
Tadjourah ville	50	41	15	44	8.4	1.5
Randa (1)	11	90	10	0	10	
Ewali (1)	10	100	0	0	7.5	
Obock	50	17	14	69	7.5	2
Ali Sabieh	50	12	12	76	8.5	
Hol Hol	9	-	33	67	5.5	1.16
Goubetto	5	100	-	-	8.6	
Dasstiyau	10	30	20	50	8.2	2.2
Dikhil (exc. refugees)	35	11	9	80	8	1.6
As Eyla	10	80	10	10	7	2
Yoboki	10	70	10	20	8	2
Refugee encampment at Dikhil	13	60	20	20	11.7	
					mean = 8.24	

(1) Estimate based on a 7 day survey of consumption.

This table shows that a large majority of the urban population cooks with kerosene: 76% in Ali Sabieh and Dikhil (not counting the refugees), 69% in Obock. Only in Tadjourah is wood still used as the principal cooking fuel since only 44% of the population uses kerosene. The refugee camp in Dikhil was surveyed separately; 80% of these households cook with wood.

In the rural centres, those close to Djibouti ville (but also along the Djibouti-Addis railway) tend to mainly cook with kerosene. However, the centres further away from the capital (As Eyla, Yoboki, Randa) for the most part use wood.

The surveys also show that all families use wood for certain ceremonies and fêtes, and that almost all families use charcoal for additional uses such as burning incense, making coffee, smoking tobacco using water-pipes, and as mosquito repellant.

As for the collection of wood, only a few families in the urban centres collect the wood themselves. However, in the smallest towns the wood is collected directly for use.

d) Cooking: Quantitative Analysis

A survey of household wood consumption was conducted in the region of Tadjourah-Randa taking a sample of 42 families.

This survey was carried out by weighing each day the wood (and where appropriate the kerosene) used by each household. These checks were performed every day for a week. Table 1.1.15 shows the results of this survey.

Over the total area studied, consumption per day and per person was found to be relatively homogenous :

Tadjourah	538 g
Randa	611 g
Ewali	529 g
Overall mean:	565 g

The figure of 565 g of wood per person per day is the figure retained as the basis for calculating total consumption. By comparison with consumption in other arid countries of Africa (685 g in Niger, for example, in the urban areas), the figure obtained for Djibouti is significantly lower.

The difference could be due to differences in the kind of foods cooked -- those in Djibouti perhaps needing less preparation and shorter cooking times.

Table 1.1.15 Consumption of Wood and Kerosene in the Region of Tadjourah

	average family size	consumption of wood per person g/day	consumption of kerosene per person, ml/day	families purchasing wood, %
TADJOURAH				
- total families	10.6	436	160	95
- families cooking only with wood		538	61	
- families cooking with both wood and kerosene		335	258	
RANDA	10.1	611	150	40
EWALI	7.5	529	58	0
RANDA + EWALI	8.8	578	113	
Total families cooking with wood		565	94	
Total families surveyed	9.7	501	138	

Based on the analyses presented above, Table 1.1.16 shows the consumption of energy for cooking in the Districts.

An estimation of the quantities of charcoal consumed annually is more difficult since a large number of households using wood as fuel recover the charcoal for later use. The figures presented in Table 1.1.16 do not include this consumption.

The calculation of kerosene consumption in the Districts is based on a mean consumption of 0.9 litres per household per day.

Table 1.1.16 Consumption of Energy for Cooking in the Districts

	Ali Sabieh	Dikhil	Tadjourah	Obock	TOTAL	TPE
Wood (tonnes)	470	350	750	230	1800	660
Charcoal (tonnes)	52	35	20	17	124	82
Kerosene (m3)	759	400	228	198	1585	1277
LPG (tonnes)			a few households		12	12
TOTAL						2031

1.1.1.3. Rural Populations

a) Electricity Demand

Strictly speaking there is no demand for electricity in the residential sector of the rural population. The few Diesel generators which exist in the rural areas are used exclusively for water pumping and will be accounted for in section 1.1.2.4.

These populations do not have refrigerators or fans; lighting is by wood fires, or occasionally by kerosene lanterns. Water pumping, when the population is not near a well or a borehole, is generally done with human energy by lifting water with a bucket.

b) Cooking

With a few rare exceptions, cooking is done with wood over 3 stone fires. The wood is collected from around the encampment and later used for cooking and lighting.

The total consumption of wood by district was estimated by Briane /1.3/. The figures given in Table 1.1.17 are taken from that report.

Table 1.1.17 **Consumption of Wood For Cooking in the Rural Areas**

	Ali Sabieh	Dikhil	Tadjourah	Obock	Consumption, tonnes	Total in TPE
Total annual wood consumption (tonnes)	8300	6600	5700	1900	22500	8295

For the purposes of modeling this aspect of energy consumption the use of fuel other than wood can be considered negligible.

1.1.2. The Service Sector

The sectoral analysis of Djibouti depicted in the document "DJIBOUTI, projet de développement urbain", prepared in 1983 by the World Bank with the collaboration of the "Groupe Huit Sedes", began:

"The Djiboutian economy is marked by a preponderance of service activities, due not only to its limited natural potential but to the presence of a large expatriate community, and to the importance of the regional transport and commercial activities which are supported by the rail-port-airport-telecommunications network which services a hinterland extending far beyond the borders of the country".

Even if the situation has evolved somewhat since that time, this statement remains true in 1985, and this sector requires a particularly careful analysis with regard to its energy demand.

The study of this sector's energy use will cover government and public services, businesses, banks and insurance companies, hotels, bars and restaurants, as well as the supply and pumping of water.

Table 1.1.18 shows the importance of each of these subsectors in the national economy.

Table 1.1.18 Structure of the GDP (1983) excluding Import Duties and Taxes

	Percentage of the service sector	Percentage of real GDP
Government, and public services	61.8 %	47 %
Commerce, banks, insurance	25.2 %	19.2 %
Hotels, bars, restaurants	7.8 %	5.9 %
Water supply	5.2 %	3.9 %
TOTAL service sector	100 %	76 %

1.1.2.1. Government Administration and Public Services

The masterplan of the Directorate of Public Housing prepared in November 1983 /1.1/ described the administrative situation as follows:

"The predominance of government and administrative offices within the city did not take place in a uniform and balanced fashion throughout the urban perimeter. It was concentrated in one section of the city: the administrative and commercial sector..."

This situation has only slightly changed with the decentralization of certain public services (Ministry of Public Works, ISERST...) to the outlying areas, and with the establishment of various small enterprises which have created new jobs. However, the administrative sector is still the main source of employment in the country: 40% in the Government and its administration, 13% in the transport sector and telecommunications, 5% for the National Water Authority (ONED), and Electricité de Djibouti etc...

The Cité Ministérielle, Peltier Hospital, the National Security Force (FNS), National Education, the Djiboutian National Army, the District of Djibouti as well as various ministries and other public services employ substantial numbers of people.

Within the Districts, Government jobs are not numerous even though the government has made an effort to provide services to these areas (schooling, development of water points, establishment of dispensaries, etc.).

The major part of the demand for energy in this sub-sector therefore originates in Djibouti ville. This demand concerns gasoline, kerosene, Diesel fuel and electricity. Although a small amount of wood and charcoal is consumed in this sub-sector, it is negligible, and will not be taken into account in the section which follows.

a) Gasoline.

The demand for gasoline is essentially created by the government's fleet of vehicles (registered as A, B or C), military vehicles, etc. Estimates based on information provided by Total, Shell and Mobil give a consumption of 640 TPE for this sub-sector.

b) Kerosene.

Kerosene is used mainly for cooking in certain institutions (prisons, the hospital etc.). Consumption is about 49 TPE per year.

c) Diesel Fuel

Information provided by the three oil companies permits a fairly precise breakdown of Diesel fuel consumption.

Total demand is about 1880 TPE distributed among the principal users as shown in Table 1.1.19 below.

Table 1.1.19 Consumption of Diesel Fuel by Government and Public Services in 1985

	Consumption TPE
National Army	891.3
Port	435.4
Road services	215.0
Airport and Air base	204.0
Other services	134.3
TOTAL	1880

d) Electricity

Electric power consumption reached 22,955 MWh, or 1975 TPE, primarily in the mid range voltage.

Demand is mainly for air conditioning, lighting, ventilation and in certain cases refrigeration (refrigerated warehouses in the port, for example).

Apart from certain specific needs for activities such as the terminal containment center at the port, there also exists an energy demand for office machines and equipment.

Table 1.1.20 gives a list of the services which consume the most energy. This list is important because it allows one to rank future energy conservation activities according to the importance of their potential impact.

Table 1.1.20 Consumption of Electricity by Government, Public Services, and Other Large Users (MWh/year); Data from EdD.

	1983	1984	1985
Peltier Hospital	1613	1404	2057
Doraleh radio/TV station	801	784	1066
Airport	nc	1168	1058
Cité Ministérielle	677	646	682
STID	nc	nc	602
Cold store depot at the port	166	793	568
National Security Force	nc	nc	538
Post Office and Telephones (OPT)	nc	nc	499
Palais du Peuple	nc	nc	482
STID (emission)	nc	nc	443

nc = not communicated

1.1.2.2. Commerce, Banks and Insurance Companies

Energy demand in this subsector deals exclusively with electricity since consumption of kerosene, LPG or diesel is negligible.

a) Commercial Sector.

Energy consumption in the commercial sector is dominated by the three largest supermarkets in Djibouti ville: Pierront, Prisunic and Semiramis. These supermarkets are air conditioned throughout the year, and offer fresh produce from Europe which requires refrigeration and sometimes freezing for its conservation.

The other major use of electricity in this subsector is for artificial lighting since natural lighting was not taken into consideration when these stores where built.

A number of small businesses in the towncenter (hardware stores, bookstores, household appliance stores...) are also air conditioned. The stores are generally much smaller, so their demand is not comparable with that of the three supermarkets.

There is a third category of stores in the town center which covers a variety of stores (notions, pharmacies, tailors, groceries, etc...). These stores do not use air conditioning; their only real use of electricity is for lighting, usually fluorescent, and for ventilation with electric fans.

Small kiosks are scattered throughout the city as well as throughout the towns and villages of the interior. These sell beverages, dairy produce, canned goods, etc. Each kiosk has one or two lights, a ceiling fan and a refrigerator-freezer for cold drinks. This last appliance is obviously the one which imposes the greatest energy demand.

Finally, it should be noted that a great deal of business is conducted outside of any well-defined commercial structure: the central market is such an area, as well as certain streets of which the "Rue des Mouches" is a typical example. This type of commerce does not involve any significant energy use.

b) Banks and Insurance Companies.

The banking system consists of a few large firms located in the centre of Djibouti ville, supported by a number of small branch offices in the quartiers.

Most of the energy is consumed in the main offices and is mostly for office equipment, lighting and, above all, for air conditioning.

Insurance companies are in relatively small offices for the most part and do not figure in the list of major consumers in this sub-sector which is given in Table 1.1.21

Table 1.1.21 Consumption of Electricity in the Principal Commercial Enterprises and Banks, MWh/yr.

	1983	1984	1985
Pierront (supermarket)	737	740	873
Prisunic (supermarket)	673	807	799
B.C.I.M.R. (bank)	nc	nc	426
Sémiramis (supermarket)	376	370	420
B.I.C.S (bank)	nc	nc	404
British Bank of the Middle East	nc	nc	133

1.1.2.3. Hotels, Bars and Restaurants

a) Hotels

According to the table taken from the 1985 Statistical Yearbook showing the number of hotel registrations for that year, a total of 316 rooms were available in the 5 major hotels surveyed by DINAS (Sheraton, Plein Ciel, Palace, Ali Sabieh, Menelik) with an average occupancy of 50%.

These statistics deal only with the five hotels mentioned above, but there are also other hotels within Djibouti ville of comparable standing (La Siesta for example) or of a lesser quality. These hotels significantly increase the number of rooms available in the city.

This capacity permits the city to host international conferences or to handle sudden demands such as that which occurred during the events in South Yemen in January 1986.

Outside o´ Djibouti ville the hotel industry remains extremely limited even though the Tourist Office has been encouraging the development of hostels in the interior of the country (As-Eyla, Ali Sabieh, le Day, for instance).

The energy demand for this subsector is essentially for electricity: for air conditioning (a central system in the case of the Sheraton Hotel, individual room units in the other hotels), lighting, fans, and miscellaneous units such as television, irons, etc.

In certain cases, there also exists a demand for petroleum fuels for water-heating or for generating steam for laundry (the Sheraton, for instance), or for the generation of electricity in remote areas--the hostel at Ali Sabieh for example.

b) Restaurants.

This subsector groups all restaurants, whether air conditioned or not, offering regional, oriental or western cooking. Outdoor restaurants are also included. The latter are most often located along the sidewalks of the main avenues and offer local cooking.

With the exception of a few speciality restaurants using wood for cooking (baking fish in ovens), or charcoal (grilled meats, brochettes etc...), cooking is done on kerosene stoves by outdoor restaurants, or on electric stoves by other restaurants for reasons of safety. LPG stoves are less common.

There is also a secondary demand for lighting, for ventilation and for air conditioning. However, energy demand remains rather low because of the small size of the rooms and the way in which the rooms are used (lunch and dinner only). In a hotel and restaurant complex, the demand is of course much higher as shown in Table 1.1.22 below.

Table 1.1.22 Consumption of Electricity in Hotels with Restaurants, MWh

	1983	1984	1985
Sheraton	3163	2891	2742
Plein Ciel	nc	nc	390
Ménélik	nc	nc	325
Ali Sabieh	nc	nc	234
Siesta	nc	nc	92

c) Bars

Djibouti ville has a large number of bars and taverns which are well patronised in the evening and at night.

These establishments use electricity for lighting, fans, and for air conditioning. Their individual consumption is relatively modest.

d) Total Subsector energy demand.

The total energy demand by this subsector is shown in Table 1.1.23. Total consumption is estimated at 7,065 TPE, to which should be added a small quantity of wood and wood charcoal.

Table 1.1.23 Energy Consumption in the Service Sector (TPE)

	Petroleum Fuels					Electricity	Total subsector
	LPG	Gasoline	Kerosene	Diesel	Total		
Administration, and Public services		640	49	1880	2569	1975	4544
Commerce, Banks, and Insurance						660	660
Hotels, Bars, and Restaurants	71		610			617	1298
Public lighting						155	155
Water pumping						408	408
TOTAL	71	640	659	1880	3250	3815	7065

1.1.2.4. Water Supply and Pumping.

Physical and Socio-Economic Background.

Rainfall in Djibouti is very low and irregular (see Figure A 1.2 and Table A 1.2), and often causes flooding--2 to 8 floods per year depending on the region. The rainfall supplies the subterranean aquifers which flow to the sea. These floods create soil erosion and cause great difficulties for the nomadic tr[illegible]s and their livestock, as well as for the small farmers along the banks of the rivers.

In addition, drought has scattered the small herds of livestock, and threatens one third of the population. Desertification is overtaking the country's limited pasture lands.

However, the maps presented in the annex show the quality and depth of the subterranean water resources, and offer a degree of optimism regarding the possibility of irrigated agriculture and intensive livestock raising.

Djibouti, a country of nomadic traditions which depended until recently on its livestock, now imports almost all of its food principally from Ethiopia and from France. This dependency represents an significant part of the trade deficit. But the high prices of these imported products provides an important incentive for the development of agriculture.

The absence of any permanent water courses makes water pumping an absolute necessity. Energy consumption for water pumping and the transportation of water is only a very small part of final energy demand, but the cost of energy is an important component of the cost of pumping water.

The contribution of agriculture to the GDP, currently 4%, is expected to become more important in the future, and the essential role of energy in irrigation underscores the importance of energy in the pumping of water in Djibouti.

Political and Institutional Setting

The National Water Commission formulates policy with respect to water resources. The Commission is presided over by the Ministry of Agriculture and Rural Development, and is made up of the Ministry of Health, the District of Djibouti, as well as ISERST.

The different institutions concerned with the problems of water supply are:

- ONED, the National Water Office, which is part of the Ministry of Industry and Industrial Development, has the responsibility for the water supply in the urban zones (Djibouti ville, Tadjourah, Obock, Dikhil, Ali Sabieh, Arta and Oueah).

- Rural Engineering (Genie Rural), a part of the Ministry of Agriculture and Rural Development, is responsible for water supply projects in the rural areas of the country.

- The District of Djibouti, a part of the Ministry of the Interior, is responsible for the water supply of Djibouti ville. This office is also responsible for the supply of water to the nomadic population and its livestock living within the district who are victims of the drought.

- The four other Districts of the country, in addition to ensuring the water supply to their smaller urban centres, are responsible for providing water to the nomadic populations and their livestock from wells or boreholes.

- ISERST, which falls under the office of the President of the Republic, is responsible for studies and research on water resources, as well as for the development of renewable energy technologies for water pumping in the rural areas.

Water policy in Djibouti aims at the following:

1) ensuring the water supply for the large urban center of Djibouti ville and the towns of the interior.

2) developing water sources (boreholes, wells, dikes, etc.) in the struggle against drought, as well as assistance for the development of irrigated agriculture.

3) providing water to the nomadic populations and their livestock, victims of the drought.

The Urban Zones

a) <u>Consumption and Need for Water</u>

Population estimates in the various towns together with a per capita water requirement of 100 liters per person per day have been used to estimate the need for water of the urban population. Consumption figures were provided by ONED.

Table 1.1.24 shows that a consumption of 100 liters per day per person was far from being reached in 1985. This was particularly true of Ali Sabieh and Dikhil.

Table 1.1.24 Annual Consumption and Needs for Water in the Urban Centres, 1985

	(a) Djibouti ville Arta, Oueha	Ali Sabieh	Dikhil	Tadjourah	Obock	Total
Population (c)	250,000	22,500	22,500	7,500	6,400	308,900
Water needs (thousand m3)	9,125	821	821	274	234	11,275
Consumption billed (b) (thousand m3)	7,612	181	236	163	139	8,331
Consumption (l/capita/day)	83	22	29	60	60	74
deficit (thousand m3)	1,513	640	585	111	95	2,944

a) Djibouti-ville, Arta and Oueha are grouped together.
b) Annuaires Statistiques /1.5/. For Djibouti ville, 75% of the total is assumed to be for household use.
c) The population figures shown here are those supplied by ONED.

ONED is currently faced with a situation where the demand for water is increasing, but where borehole installations are limited, and a somewhat decrepit and undersized network can not ensure the water supply required.

Distribution losses (leaks, consumption not accounted for, water used for firefighting etc..) represent a significant part of production -- 30% in Djibouti ville, 23% in Ali-Sabieh, 17% in Arta-Oueah, 13.5% in Tadjourah, 15% in Obock and 17% in Dikhil.

These problems are aggravated by the urbanization of Djibouti ville. This is mainly taking place in the suburban sector of Balbala which is principally inhabited by nomad victims of the drought, and by refugees.

The demand for water will become more and more pressing, and ONED has begun a large project to rebuild and extend its supply network, to provide hydraulic and electro-mechanical equipment, and to drill two supplementary boreholes for Djibouti ville.

This development should not only allow ONED to meet the projected demand, but will also produce economies in energy consumption.

b) Energy Demand

A volume of water, 20 to 30 % greater than that actually billed, is pumped from depths ranging from 50 m to more than 100 m. The submerged electric pumps are connected to the grid with the exception of Ali Sabieh and Dikhil which use less efficient Diesel generators.

Thus, as indicated in Table 1.1.25, energy consumption per cubic meter of water pumped is relatively high, particularly in Ali Sabieh where the total dynamic head is substantial.

Table 1.1.25. Energy Consumption for Water Pumping, ONED 1985

	Djibouti ville	Arta-Oueah	Ali Sabieh	Obock	Dikhil	Tadjourah	Total
Water pumped thousand m3 (a)	10,441	342	235	164	283	200	11,665
Energy consumption, MWh	3,984	550	782	191	113	222	5,842
Consumption kWh/m3	0.4	1.6	3.3	1.2	0.4	1.1	0.5

a) Annuaires statistiques /1.5/

The Rural Areas

Two quite distinct populations can be found in the rural areas with marked differences in their manner of living:

1) a sedentary population residing around the water points and the administrative centers (schools, district

administrations and military encampments) which is nomadic to some degree but whose transhumance is not the only source of income.

2) a nomadic population which practices wide scale transhumance in search of pastureland and which is becoming more and more constrained to existing water points because of the drought. A significant number of the nomadic tribes still practice wide range transhumance across the frontiers of Djibouti, Ethiopia and Somalia.

The total population in the rural areas is estimated to be about 100,000 people (see Table 1-1 of the Introduction).

In 1985, the water points under the dual responsibility of the Districts (operation and maintenance), and of Rural Engineering (development of the wells and installing the equipment) provided a significant quantity of water to the rural areas of the country.

A part of this volume of water is transported by water trucks over long distances to supply rural families and their livestock.

However, the greatest part of the water requirements of the nomads and their livestock is provided by rainfall, often torrential, and by some 200 wells (springs, traditional wells as well as some 60 cement wells). There are more wells in the South than in the North.

Traditional wells are dug in the wadis by nomads who must often dig them again them after each flood. However, many of these wells dry up during the dry season.

a) Consumption and Need for Water.

Estimates of the rural and nomadic population's need for water are based on a minimum consumption of 20 liters per person per day. Table 1.1.26 shows estimates of the rural and nomadic population by district, together with their estimated water needs. Also shown are estimates of the water provided in 1985 based on figures available on the consumption of fuel by motor pumps pumping from rural wells.

It is difficult to estimate the degree to which the human need for water is really satisfied in the rural areas since the consumption shown in Table 1.1.26 includes the water consumed by livestock--a very substantial consumption (see section 1.3.2).

Table 1.1.26 Consumption and Needs for Water in the Rural Areas, 1985

Population (rural and nomadic)	96,000
Water requirements for humans (1)	700,800 m3/yr
Water requirements for livestock (2)	1,177,000 m3/yr
Total water consumption (3)	925,000 m3/yr

1. Based on a requirement of 20 litres/day per capita
2. Based on a requirement of 30 litres/day per Tropical Livestock Unit
3. Human and livestock together

Nevertheless, it would appear that the need for water for the rural and nomadic population is by and large covered, except for the district of Tadjourah where it is well known that the supply of water is inadequate for the need. This district does not have enough tube wells or shallow wells.

A small quantity of well water is transported by truck to the rural nomads. The need for this action illustrates the dimensions of the water distribution problem in Djibouti. The quantity of water distributed in this manner and the distances covered are shown in Table 1.1.27. This method was not used in Dikhil in 1985.

Table 1.1.27 Provision of Water by Truck in 1985

District	Obock	Tadjourah	Ali Sabieh	Djibouti	Total
Quantity of water supplied, thousand m3/year	0.5	4.8	5.4	5.8	16.5
Distance covered, thousand km/year	5.7	57.1	15.6	10.9	89.3

b) Energy Consumption

Table 1.1.28 shows the quantities of water pumped and delivered by truck, and the amount of fuel used for these tasks.

Table 1.1.28 Energy Consumption for the Provision of Water in the Rural Areas

Pumping	
Volume of water pumped	952,000 m3/yr
Fuel consumption for pumping	124.6 m3/yr
Fuel used per litre of water	0.131 litres/m3
Truck delivery	
Volume of water delivered	16,500 m3/yr
Fuel consumption for delivery	44.3 m3/yr
Fuel used per litre of water	2.7 litres/m3

From the above table it may be seen that about 125 m3 of fuel was consumed in pumping approximately 0.95 million m3 of water from the wells in the rural areas. A small part of this amount, about 16,500 m3, was distributed by truck in the different localities with a consumption of 44.3 m3 of Diesel fuel--about one third of the energy used for pumping.

Table 1.1.28 clearly shows the heavy energy consumption per cubic metre of water delivered for the water distributed by truck.

In conclusion, in 1985 the wells in the rural areas only satisfied about 50 % of the need for water. The energy consumption for water pumping and for delivering water by truck was about 150 TPE.

1.1.2.5 Public lighting

Although public lighting is of importance in all the urben areas in Djibouti, the consumption of energy in this sub-sector is almost entirely in Djibouti-ville.

In 1985 the capital had 2,400 lights installed of which approximately 2,300 were mercury vapour lamps, the remainder being high pressure sodium lamps. The luminous flux of the lamps, particularly the mercury vapour lamps, is often insufficent for adequate illumination. This fact contributes to the high level of nighttime vehicle accidents.

To improve this situation the District of Djibouti intends to significantly raise the quality of the lighting; these measures are discussed in more detail in chapters 5 and 9.

The energy consumption of this subsector was close to 1800 MWh of electricity in 1985 - a little more than 1% of the total electricity consumption for the country.

1.2 INDUSTRY AND CONSTRUCTION

The industrial and building sectors represent approximately 7.5% of the GDP. The Coubeche Company, which produces soft drinks (Coca Cola) and blocks of ice, is the largest industry in Djibouti. The building sector is dominated by Union Engineering, the contractor building the Route de l'Unité between Djibouti ville and Tadjourah.

1.2.1. Industry

The industrial sector in Djibouti suffers from the cost of energy and of local labor which, even though relatively modest, appears to be higher than that found in countries where the situation is similar.

Aware of this problem, the public authorities are currently reviewing ways of reducing the price of medium voltage electricity in order to increase the competitiveness of local production.

For these and other reasons, the industrial sector exports very little merchandise or produce. Almost its entire production, predominantly food processing, is marketed locally. The three major companies in this sector are the Coca Cola and ice-making factory, the water bottling factory at Tadjourah, and the Djibouti dairy.

In 1986, industrial activity was reinforced by the startup of a flour mill located in the port area. Several associated projects (biscuits, pasta, etc.) are expected to begin soon.

Other projects, such as the cement factory proposed for the region of Ali Sabieh, could increase the importance of the industrial sector in the national economy.

The following paragraphs briefly review energy consumption by the principal industries.

a) <u>The Coubeche Company</u>

This company, whose activities include many which are outside the industrial sector (the Semiramis Supermarket, the Hotel Plein Ciel), operates the Coca Cola company.

The company was very important before refrigerators became widely available, but now the production of ice is expected to diminish over the next few years. Production exceeded 4,900 tonnes in 1984, rose to 5,150 tonnes in 1985, but is not expected to exceed 4,600 tonnes in 1986.

Energy consumption for this production is estimated at approximately 100 kWh per ton of ice.

The consumption of Coca Cola is also decreasing, and estimates for 1986 are lower. The departure of a part of the population for Somalia or Ethiopia during the hot season also reduces the demand since the hot season is traditionally a period of heavy consumption.

Table 1.2.1 summarizes energy consumption for the production of ice and Coca Cola in 1984 and 1985.

Table 1.2.1 Energy Consumption by the Coubeche Company for the Manufacture of Ice and Coca Cola

	1984	1985
Electricity (kWh)	2,408,000	2,302,500
Fuel oil and Diesel fuel	583,000	616,000
of which trucks:	63,000	72,000
(litres)		

b) Tadjourah Springwater Bottling Plant

The factory which bottles Tadjourah springwater has been in operation since 1981.

The factory, located in Tadjourah, sends the majority of its production by ferry or barge to Djibouti ville. This method of transport costs approximately 10 francs per bottle and significantly increases the retail price.

The factory uses only one form of energy: electricity produced by the EdD power station in Tadjourah. The installed capacity, about 100 kW, is used for pumping, the fabrication of bottles, water treatment (using ozone, U.V., etc...) and the production process.

Average production is about 1,500 cases per day, or 18,000 bottles. The maximum capacity of the factory is around 5,000,000 bottles per year.

Table 1.2.2 shows the production of bottled water and the consumption of electricity for the past two years:

Table 1.2.2 Consumption of Electricity for Tadjourah Water

	1984	1985
Electricity (estimation) kWh	320,000	310,000
Production No. cartons (12 bottles)	338,000	250,000

c) The Djibouti Dairy Company

This company, like the Tadjourah Bottling Company, is a nationalized industry which forms part of the base for Djibouti's food production sector.

The dairy uses two sources of energy:

1) Fuel oil for generating steam used for washing, pasteurization and sterilization. Average consumption of fuel is about 6,000 liters every 65 days, or 92 liters per day.

2) Electricity for motors, centrifuges, compressors, lighting and air conditioning. Daily consumption varies but is generally around 2,000 kWh.

The total monthly production of the dairy is about 250,000 liters. The managers believe that future production might rise to about 400,000 liters per month.

Table 1.2.3 shows this company's energy consumption in 1984 and 1985.

Table 1.2.3 Consumption of Energy of the Dairy

	1984	1985
Electricity (kWh)	235,275*	679,400
Diesel fuel (estimated) (litres)	nd	33,700

* The dairy started production in 1984
nd: no data

d) <u>The Flour Mill</u>

This mill, which is privately financed with SOPINAD funds, became operational in mid-1986. When in full operation, it will process 18,000 tons of wheat per year and will produce 13,500 tons of flour.

The estimated energy consumption, mainly electricity, is about 80 kWh per ton of wheat, or a total demand of approximately 1,500 MWh per year.

1.2.2. Construction

The construction sector concerns three main activities: buildings, roads, and other construction projects (airport, port, etc.). A review of each of these sectors is given below.

a) Building Construction

As shown in Table 1.2.4, which is based on data taken from the annuaires statistiques /1.5/, building activity has seen a noticeable slowdown in 1985 mainly in the public sector where the area under construction was only a quarter of the area constructed in 1984 or 1983.

Table 1.2.4 Building Construction from 1983 to 1985

	1983	1984	1985
Public buildings surface area (m2)	28,777	31,231	7,411
Private buildings surface area (m2)	76,305	48,732	46,525
Number of construction permits (simplified)	38	57	40

The building market is shared among several small and medium-sized civil engineering firms which are taking on fairly small contracts.

In fact, after the large construction contracts which followed Independence (the Sheraton Hotel, the People's Palace, the Ministry of Foreign Affairs, etc...), the construction firms are now faced with a depressed market. The size of the contracts is smaller and this has led to a degree of restructuring of the firms.

The impact of this situation on energy demand was immediate, and the demand for Diesel fuel (for motors) and for electricity decreased considerably.

In addition, overall energy demand is the sum of the individual demands of the work in progress, and therefore varies according to the amount of construction underway.

b) Road construction

Variability of energy demand is also a feature of this sub-sector.

In addition to the basic construction and maintenance work carried out by the Ministry of Public Works and the Districts, there may also exist occasional projects whose size may dominate the sectoral energy demand. This is precisely the case at the present time.

The Ministry of Public Works has a large fleet of trucks and construction vehicles used for the maintenance of existing roads and the construction of new roads (in 1986, the road between Dikhil and As-Eyla, for example). The consumption of fuel of the 40 largest trucks belonging to Public Works was approximately 150,000 liters in 1985.

This demand is, however, very low compared to that of the Route de l'Unité construction project between Djibouti ville and Tadjourah. This project began at the end of 1985 and will continue until mid-1988. It is being carried out by the Union Engineering Company under the supervision of the Ministry of Public Works.

The size of this project is exceptional for Djibouti (170 km of road to be constructed across rough terrain) and its impact on energy consumption, which was felt as early as 1986, will be significant. Union Engineering estimated that its purchases of gasoline and Diesel fuel in 1986 would be 5,000 liters and 4,000,000 litres respectively.

This demand of approximately 3,300 TPE will double the demand of the industry-construction sector, and represents approximately 5% of total national energy consumption. These two figures show the importance of this construction project on the energy balance.

Should this demand be taken into account when projecting energy demand over the short and medium term, or should it be considered an event which is unlikely to be repeated?

In fact, even if the projections made by Union Engineering show an increase in consumption for 1987 (5,500 liters of gasoline and 5,500,000 liters of Diesel fuel), 1988 should see a sizeable decrease in fuel consumption which will eventually drop to zero when this project is completed.

This demand should therefore be considered as a one time event and it should not be taken into consideration when modeling future energy demand scenarios.

c) Other Activities

The same question can be posed for other projects being undertaken such as the extensions to the Port and the airport, and the geothermal research and development project.

As far as the port and the airport is concerned, these extensions should be considered as part of the normal program of construction and development undertaken by the state.

The geothermal project is different both because of its importance and its character. This project, which began in early 1987, consists of several phases whose characteristics will depend on the results obtained in the field. Energy demand will be intermittent and spread over a number of years, and will have an impact at the sectoral level which will need to be taken into account in modeling this sector.

The consumption of Diesel fuel in 1987 is estimated to be approximately 1,000,000 liters for project equipment, and for the production of electricity by Diesel generators.

Total Energy Demand By Industry and Construction

The total demand for energy by this sector is shown in Table 1.2.5.

Table 1.2.5 Total Energy Consumption by Industry and Construction 1985, TPE

	Diesel	Electricity	Total
Annual consumption of energy by the construction sub-sector	3,161	436	3,597

1.3. AGRICULTURE, LIVESTOCK RAISING AND FISHING

1.3.1. Agriculture

Agricultural activity in the Republic of Djibouti only started to develop about 50 years ago. At that time, the country was inhabited mainly by nomads living on the products of their livestock, and by a settled population attracted by the activities flourishing around the port of Djibouti ville and the railroad.

In addition, the particularly difficult climatic conditions, and the lack of water and irrigable lands did not encourage the development of agriculture.

The urbanisation of Djibouti ville, and that of the towns in the interior of the country, has created a sharp increase in the demand for agricultural products. Given the degradation of the land by drought, overgrazing and desertification, agriculture is a less risky proposition, and provides an important source of income for a significant part of the population.

The Government of Djibouti has made the development of agriculture a priority. Thus, since the country's independence, this sector has shown quite rapid development.

The total land area used for agriculture increased from 100 to 400 hectare between 1978 and 1985, and agricultural production, which for a long time was almost negligible, accounted for 12.9% of the 10,000 tonnes of fruits and vegetables consumed locally in 1985.

The number of people dependent on the agricultural sector is estimated to have tripled during this period and today numbers about 10,000 people.

In 1985, the number of small market gardens was estimated at about 1,000. The largest agricultural centers are organized in the form of cooperatives and are therefore better able to market their produce in the urban centers, particularly in Djibouti ville. Production is almost entirely vegetables, except for the PK 20 Project where the large scale production of jojoba is being attempted.

Because of insufficient and irregular rainfall, only irrigated agriculture is possible in Djibouti. In the majority of cases, water is drawn from shallow wells of about 6 meters depth supplied by phreatic aquifers.

Although there are a few government sponsored agricultural projects irrigated by deep wells (with a total area of about 70 hectares of which the project at PK 20 accounts for 50 ha), small-scale agriculture is much more important, and has so far been the most successful. Most of the plots, which vary between 0.2 and 0.6 hectare, are situated on the edges of the wadis.

The "chadouf", the traditional technique for lifting water, is used now much less frequently, and is being replaced by 2-4 HP motor pumps.

The volume of water used by small scale agriculture in 1985 is estimated at about 7.5 million m3, with a fuel consumption (Diesel fuel or gasoline) of around 340 m3.

For several years, the small farmer has faced a growing problem of water salinity. Over a period of about 5 years, the salt ruins the soil and makes the shallow wells useless. One reason for this progressive salinization is that the motor pumps are too large in comparison with the capacity of the wells.

Pumps which have an output of over 9 m3 per hour are often used on wells whose sustainable output is less than 3 m3 per hour. As a result, the pumps often run for only an hour in the morning, and an hour in the afternoon.

1.3.2. Livestock Raising

An estimated 100,000 people in Djibouti are involved in raising livestock and in animal husbandry. The last census of livestock numbers taken in 1978 counted 40,000 cattle, 400,000 sheep, 500,000 goats, 50,000 camels, and 6,500 asses, altogether the equivalent of 155,000 TLU (Tropical Livestock Units) /1.6/.

Recent estimates of livestock numbers in the vicinity of the water sources in the Districts, give a figure of 108,000 TLU, i.e. a number significantly less than that counted in 1978.

The traditional methods of livestock rearing have hardly changed since the beginning of the century. The animals provide meat and milk to those who tend them. The contribution of this activity is not included in calculations of the national economy. In addition, Djibouti is a transit point for the re-exportation of livestock from Ethiopia and Somalia.

The exploitation of the local meat industry thus appears to be of secondary importance.

The traditional nomadism, although declining, continues to be supported by a sector of the urban population whose outlook to some extent remains nomadic.

In the future, the linking of livestock raising with agriculture might permit a more intensive livestock farming. Some shifts in this direction are already observable; for example, forage crops are being grown in some areas.

1.3.3. Fishing

Djibouti is turning more and more towards the sea to exploit its abundant resources of fish.

Without threatening the marine environment, the sea could produce about 5,000 tons of local fish, and more than 9,000 tons of migratory fish per year.

Production of all types of fish was slightly over 600 tons in 1985. This suggests that a potentially important source of food is available. The Boulaos fishing project leads the development of the Djiboutian fishing industry, and its immediate impact was an increase in the sale of fish in 1986 as well as the establishment of an export market principally with Reunion and Saudi Arabia.

With regard to energy use, the fishing activity consumes a significant amount of electricity (for the freezing of the fish), and of Diesel fuel and gasoline for the operation of the fishing vessels.

a) <u>Electricity</u>

The Boulaos installation consists of a freezing chamber, two ice-making plants (with a capacity of 1.5 and 3 tons per day), two 15 m3 refrigerated chambers, and two 50 m3 freezer chambers (-18°C and - 20°C).

Electricity consumption is roughly constant throughout the year. Consumption in 1985 was approximately 447,000 kWh.

b) Diesel fuel

The small fishing boats used approximately 1,000 liters of Diesel fuel per month; the three large fishing vessels consume 2,500 liters per month. Total annual consumption is therefore estimated at 42,000 liters of Diesel fuel.

c) Gasoline

The fleet of 80 small fishing boats uses gasoline engines. Monthly gasoline consumption is about 8,000 liters, or 96,000 liters for 1985.

It should be noted that the fishing industry is gradually replacing the gasoline engines, and expects to have the entire fleet changed over to Diesel engines within three years.

Table 1.3.2 below summarizes the consumption of energy by the fishing sub-sector.

Table 1.3.2 Energy Consumption due to Fishing in 1985

	Consumption
Electricity	447,000 kWh
Diesel fuel	42,000 litres
Gasoline	96,000 litres

1.4 THE TRANSPORT SECTOR

1.4.1. Background

The transport sector represents a major asset for the economic development of Djibouti. The influx of foreign currency, the importation of industrial products, and the access to the different parts of the country and to neighboring countries, are among the advantages of an adequate transportation system. This is especially important for a country like Djibouti where natural resources appear to be limited.

In effect, Djibouti is situated at a point which permits the convenient exchange of goods between different countries and regions of the world. The port, the international airport, the

Djibouti-Ethiopia railroad, and even the road transportation system provide for maritime, air and land traffic.

The contribution of the transportation sector (including telecommunications) to the GDP has been close to 10% during the past few years. The largest component of the sector is road transport (buses, taxis and trucks) followed by the port, then the international airport and Air Djibouti (the National Aviation Company). The Djibouti-Ethiopia Railroad Company makes the smallest contribution to the sector.

As a part of the service sector, which accounts for over 75% of the GDP, the transport sector contributes about 14%.

According to DINAS, the transport sector accounts for 14% of the salaries in the service sector.

The number of employees working in the sector as a whole, both private and government, is approximately as follows:

- Port	3,500
- International Airport	100
- Djibouti Air	200
- Railroad	250
- Bus drivers	600
- Bus assistants	500
- Taxicab drivers	500
- Truck drivers	350
- Truck loaders	350

The different parts of the transport system in Djibouti are not well integrated, and show a lack of structural balance as well as certain economic distortions.

This situation can be explained by circumstances which are specific to the country: the limited availability of natural resources, the highly concentrated population in Djibouti ville, the limited government budgets, and the attraction of activities linked to international transport.

1.4.2. Total Energy Demand and Consumption in the Transport Sector

The transport sector is the largest sectoral consumer of energy; it accounts for almost 40 % of final demand.

Table 1.4.1 presents more detailed data on the structure and activities in this sector.

Table 1.4.1 Traffic by Rail, Sea, and Air

	1979	1980	1981	1982	1983	1984	1985	79-85(1)
Rail traffic								
-passengers		1336	1204	1430	1114	947	743	- 11.1
-goods		263	211	217	241	269	294	2.3
Sea traffic								
-ships (2)	1174	1129	1122	1967	1029	937	898	- 4.4
-boats (2)	851	784	631	534	724	780	813	- 0.8
-passengers(3)	2100	2799	4174	3573	3030	3357	3199	7.3
Freight	1359	1388	1325	1381	1618	1450	1153	- 2.7
Goods	370	395	440	396	404	528	611	8.7
-embarked	120	114	135	97	115	148	140	2.6
-disembarked (4)	250	281	305	299	289	381	471	11.1
Djibouti	-	-	-	-	195	240	234	
Ethiopia	-	-	-	-	59	67	174	
Somalia	-	-	-	-	12	23	15	
Air traffic								
aircraft (2)	8091	7548	6574	6660	6915	6740	6360	- 3.9
passengers (3)	235	241	221	264	264	267	278	2.8
arrivals	59	61	64	71	64	58	55	- 1.2
departures	58	61	60	68	59	54	48	- 3.1
transit	118	119	97	130	141	154	175	6.8
freight (4)	19	8	9	9	8	8	8	- 13.4

(1) average annual rate of growth 1979-1985
(2) number of arrivals
(3) passengers in thousands/year
(4) thousand tonnes /year

units : thousands of tonnes
units : thousands of passengers

Source: Figures derived from Statistical Tables of Djibouti /1.5/.

1.4.3. Rail Transport

Although all the modes of transportation provide similar services, each finds its most important role in well-defined sectors.

Transport by rail, for example, which is provided exclusively by the Djibouti-Ethiopia Railroad Company, handles imports of fruits and vegetables from Ethiopia to Djibouti. Its activities are not limited to food imports, but include freight transport, and the transportation of cars and construction materials from Djibouti to Ethiopia, as well as passenger transportation.

The railroad, which began operating in 1918, runs over the 700 km track between the port of Djibouti and Addis-Ababa. The line in Djibouti is 110 km long and runs between Djibouti ville and the Ethiopian frontier a few kilometers from Ali-Sabieh. Each country holds 50% of the company.

The transportation of goods is determined by the demand, with two or three trains running every day. The capacity of the trains is limited by the condition of the track -- especially the section just before Ali-Sabieh.

Passenger traffic was 261,700,000 passenger-km in 1985; freight traffic was 214,690,000 tonne-km.

Railroad activities have recently been on the increase. After the closure of the less important lines, the railroad is being used more and more for the importation of food produce and the re-exportation of goods passing through the port of Djibouti and destined for Ethiopia.

As a result of this tendency, the consumption of fuel has increased by about 21% over the last few years. The consumption of Diesel fuel on the Djiboutian side has evolved as shown in Table 1.4.2. Lubricants, on the other hand, have shown the reverse tendency due primarily to the following changes:

- The retiring of several old and slow locomotives
- The acquisition of more modern equipment
- The use of new lubricants

Table 1.4.2. Consumption of Fuel by Rail Transport, m3/year

	1983	1984	1985
Diesel fuel	939	944	1,592
Lubricants	43	37	25

In the short term, an increase in fuel consumption by the railroad company will probably occur. This is likely to continue at least until the program providing emergency supplies to the refugees in Ethiopia comes to an end.

In order to handle this operation effectively, the railroad company is considering transporting 1000 tons of freight per day.

The acquisition of replacement parts for the old locomotives should no longer be a problem since the European Economic Community provided 3 million ECUS for these supplies.

1.4.4. Maritime Transport

The port is at the centre of the country's economy, both with regard to the importation of foodstuffs and other goods, and to their re-exportation.

However, since there are no Djiboutian cargo ships, imports and exports are handled by foreign ships. The cost of this service has a significant impact on the balance of payments.

Sea transport in Djiboutian waters is carried out by two ferries, named Unity and Peace, which have been in operation since 1981, and by a few private sailing vessels.

The ferries transport passengers and freight between Djibouti ville and Tadjourah and Obock.

Total fuel consumption for the two ferries in 1985 was 192,000 liters of Diesel fuel.

In transporting heavy equipment, the ferries make a contribution to the economic development of the North of the country. In the future, the role of this service may increase, encouraged by the development of small manufacturing plants in the North of the country.

On the other hand, the construction of the Route de l'Unité will lead to competition for the ferry service and this raises doubts about the proposal to purchase another ferry for the port.

There are several dhows which carry freight and passengers to Tadjourah and Obock. Most of the vessels carry between 30 and 50 tonnes of cargo, although the largest vessels can carry 80 tonnes.

1.4.5. Air Transport

The location of the Djibouti International Airport, its facilities and equipment, give it many advantages over other airports in the region. Foreign airlines flying into Djibouti, most of them in transit, account for 84 % of the airport's activity. Passengers in transit represent 63 % of the total number of passengers.

The average annual rate of increase in the number of passengers was close to 7 % between 1979 and 1985. The number of departing passengers has, however, decreased by 3.2 % per year.

87 % of the passenger traffic is handled by four companies: Air Djibouti, Cotam, Ethiopian Airlines and Air France; the rest is handled by other companies including Alyemda, Yemen Airways, Air Tanzania, Aeroflot and Somalia Airlines.

Air Djibouti, the national company which began operating in 1980, has seen a reduction in traffic since its Djibouti-Paris and Djibouti-Rome flights were cancelled. The company owns one DC9 and two DHL aircraft.

The number of passengers transported by the DHL's in 1985 was 24,100, or 47 % of the total of 51,387. The DHL's fly the shorter routes: Djibouti-Tadjourah-Obock (124 km), Djibouti-Aden (252 km), and Djibouti-Hargeisa (292 km).

However, it is the long distance flights which accounted for the major part (87 %) of passenger-kilometers travelled in 1985.

The consumption of jet fuel by Air Djibouti in 1985 was almost 5,000 m3, or 19 % of the total consumption by the transportation sector.

The extension of the Djibouti Airport will include a maintenance and service area, an industrial zone, a freight area, a presidential area, a passenger zone, and a zone for general aviation.

These additional facilities should strengthen Djibouti's international position and encourage the development of commercial and industrial activities.

1.4.6. Road Transport

Djibouti's road network of 2,905 km is divided into two categories: the national roads: 1,105 km, of which 281 km are surfaced, the rest being tracks; and the district roads, which comprise some 1,800 km of tracks.

This network connects all the towns, villages and important regions of the country, and links Djibouti with its neighboring countries. However, with the exception of the surfaced roads of Djibouti ville and of the principal rural areas of Arta, Oueah, Ali-Sabieh, Dikhil and Yoboki, through to the Ethiopian frontier, road travel is generally very difficult because of the poor maintenance of the tracks. This explains the low level of motor traffic in the country as a whole.

However, the importance of road traffic between Djibouti, Ethiopia and Somalia should not be underestimated. For example, 14,423 tons of merchandise were re-exported in 1985 from the Port of Djibouti to Somalia using the Loyoda road.

Road travel remains an essential means of communication for people and for the transfer of goods both to and within the interior of the country.

Access to the most remote areas of the country is only possible by road at the present time, since maritime transport is only just being developed, and the only aviation company in operation does not yet offer a freight service.

The fuel consumption for the road transport sector totalled 7,657 m3 of Diesel fuel in 1985.

1.4.6.1. Transportation Outside of Djibouti ville

The different modes of transportation in the interior regions of the country in 1985 are shown in Table 1.4.3.

This table, which is based on a report by the UNDP, estimates that 56% of the traffic is within 40 km of Djibouti on the Djibouti-Arta corridor. This region can be taken to represent the surburban area. The average distance travelled in this network would be 40 km.

Table 1.4.3. National Traffic by Mode of Transport in 1985

Mode of transportation	Passengers	Freight (tonnes)	Route
Maritime	30,000	nd	Djibouti-Tadjourah Obock
Air	24,000	nd	Djibouti-Tadjourah Obock
Rail	ND	2,800	Djibouti-Chebelle Goubetto Hol Hol Daasbiyou Ali Sabieh frontier
Road	1,262	1,643	Djibouti-Loyada Arta Oueah Ali Sabieh Dikhil Yoboki Galafi

(1) Data are for 1981 and are taken from a UNDP report on traffic circulation in Djibouti.
nd no data

1.4.6.2. Urban Transport

Road transport in Djibouti-ville and its suburban regions dominates, from every viewpoint, the urban transport picture. The infrastructure, equipment, employment, imports, taxes, motor fuel consumption, production costs, and mobility are the elements, inter alia, most influenced by the evolution of the urban transport sector.

The urban network is made up of 68 km of surfaced road and 83 km of unsurfaced roads (excluding Balbala). The primary road system allows for adequate circulation within the city (except at certain intersections and roundabouts, for example).

On the other hand, the secondary network makes circulation between sections of the city extremely difficult, principally because of the poor state of the roads. The area North of the city to the center of town is probably the best served from the point of view of the urban road system.

Quartiers 1 to 7 have narrow streets which are often poorly maintained. Road conditions in Ambouli are better. Balbala is the worst point in the network.

Distances traveled are short despite the triangular shape of the city, the port and Balbala (the extremities) being less than 12 km apart. However, there is heavy traffic between the port and Ambouli.

Taking only privately owned vehicles into account, distances traveled are shorter since most vehicle owners live in the North and the center of town.

1.4.6.3. Public Transport

Public transport in Djibouti is by bus and minibus; the vehicles carrying 25 and 15 seats respectively. There are, at present, more than 500 of these vehicles in operation in Djibouti-ville; about 50 vehicles service Ali Sabieh, Dikhil, Arta and Loyada.

Approximately 150 units are normally out of circulation for a number of reasons: under repair, lack of spare parts, or simply a lack of financial means to keep them in operation.

Taken together, public transport vehicles number 650 of which 40% are exclusively buses. The average age of these vehicles is quite low according to data from the Bureau of Statistics (DINAS). Between 1983 and 1985, 372 buses and minibuses were registered, or 53% of total vehicles in operation (Table 1.4.4).

Table 1.4.4. Characteristics of the Public Transport System in Djibouti-ville

	unit	bus	minibus	total
1. passengers transported/day	passengers	60000	90000	150000
2. vehicles in circulation	vehicles	201	302	503
3. number of places per vehicle	places	25	15	19
4. distance run per vehicle	km/an	58000	68000	64004
5. average vehicle speed	km/h	20	20	20
6. working days per year	days	288	288	288
7. working hours per day	hours	10	10	10
8. rush hours per day	hours	4	4	4
9. % of traffic during rush-hour	%	70	70	70
10. % of seats occupied during rush hour	%	40	45	43
11. passengers transported per vehicle per day	passengers	299	298	298
12. seats occupied per day on average	%	23	26	25
13. % of seats occupied during off-peak hours	%	11	13	12
14. vehicle-km/day per vehicle	km	201	236	222
15. distance/passenger/day (ave.)	km	3.9	3.1	3.5

To serve the different sections of the city, the buses travel on 7 different routes departing from Place Harbi in the town centre. Two routes go towards the port and the Peltier Hospital, two others towards Ambouli, one towards the quartier of Arhiba, one to Balbala, and the last serves the zone between the airport and the center of town. A different color distinguishes each of these routes; this simplifies travel for the passengers.

Distances and travel time vary from 3 km (10 minutes) from Place Harbi to Arhiba, and 15 km (35 minutes) from Place Harbi to Balbala (Table 1.4.5).

Bus fares are generally 30 francs; 50 francs to Balbala. Fares were set by the Government and have not been increased since 1974. Public transport vehicle owners are organized into several syndicates.

Table 1.4.5. Distances and Average Running Times for the Different Bus Routes

Route	Colour	Distance, km	av. time (1)
Port	pink		
to		2.9	7
from		2.8	8
round trip		5.7	15
Hospital	black		
to		2.7	10
from		2.2	7
round trip		4.9	17
Ambouli	green		
to		4.5	10
from		5.4	16
round trip		9.9	26
Arhiba	blue		
to		1.5	5
from		1.5	5
round trip		3.0	10
Balbala	brown		
to		8.4	18
from		6.0	15
round trip		14.4	33
Aéroport	orange		
to		6.1	5
from		6.1	5
round trip		12.2	10

1) The average time in minutes.

The advantages of the present system are its flexibility, the fares, the lack of subsidies by the Government, the good distribution of the network (the different routes were established by the District in 1984), the cost of vehicles compared with the cost of large buses in other countries, the employment generated, and the rapidity of travel.

On the other hand, the inconveniences of the system weigh heavily on the economy and on the population: for example, the excess of buses and minibuses given the demand, the underutilization of the buses, the excessive consumption of fuel, the traffic jams created by the vehicles at certain places, the high rate of accidents, the lack of security, and the lack of comfort for the passengers.

1.4.6.4 Private transport

The registry of the District of Djibouti's Mining Service shows that 1204 cars were registered in 1985 compared with 436 in 1977--an average increase of 13% per year. Sales of 4-wheel drive vehicles increased by 40% between 1983 and 1985.

The selection of 4-wheel drive over other models has become a fashion which is also followed in other countries. The reason often given for purchasing this type of vehicle is that 4-wheel drive vehicles are more appropriate for the tracks in the rural areas of the country. However, this reason would seem to be invalid since most of these vehicles are driven within the city and only rarely in the bush.

The large increase in the purchase of vehicles is a recent phenomenon. It is only since 1977, the year Djibouti became independent, that sales of vehicles in the city started to increase markedly.

Private transportation accounts for 10,382 m3 of gasoline and 9,935 m3 of Diesel fuel annually.

1.4.6.5. Transport of Goods via Truck.

The lack of well-established maritime and air freight transport means that transport via truck is the only possible alternative for certain goods being shipped to the neighboring countries.

It was only after 1980 that the use of trucks as a means of transport began to develop. This growth is continuing, with much larger and heavier trucks now in service.

The fact that the International Port is located within the city of Djibouti makes the capital a redistribution center for goods and freight arriving from many different countries.

Transport of goods to the interior

The transport of goods is not well developed in the interior of the country, mainly because of the poor condition of the roads and tracks.

Of the 2,905 km of existing roads, only 10 % are surfaced, the rest consisting of more or less usable tracks and trails. This reduces delivery to places like Goubetto, Oueah and Hol Hol to one or two trucks.

At Dikhil, generally considered the second commercial center of the country, many small businessmen bring in goods from the capital and resell them in the area.

A redistribution network also exists in Tadjourah which receives its goods via the ferry. This type of commercial activity appears to be the best organized in this region.

Ninety percent of road traffic is made up of small trucks which supply goods and foodstuffs to the most distant places such as Airi, Guirori, Assa Gayla, Dorra, Randa and Kalassa.

The condition of the roads is an important factor in the development of the transportation of goods by truck. The construction of the Route de l'Unité points out the government's willingness to promote this sector of the economy.

Transport of Goods by truck to Somalia

The transport of goods to Somalia is generally carried out using 6 ton trucks. These trucks are fitted out in such a way that they can carry both freight and passengers.

In 1985, 14,423 tons of goods were reexported by truck from the international port of Djibouti. This amount is significant, considering the condition of the roads, and could increase markedly as imports grow.

1.4.6.6 Summation

The total consumption of energy by fuel and by mode of transportation is shown in Table 1.4.6 below.

Table 1.4.6 Energy Consumption in the Transport Sector

	gasoline m3/an	jet fuel m3/an	Diesel m3/an	total hydrocarbons
Air transport		5478		5478
Road transport			7657	7657
Individual	10382		9935	20317
Rail transport			1592	1592
Waterway	178		690	868
TOTAL	10560	5478	19874	35912

For both gasoline and Diesel fuel, the transport sector accounts for the major part of the consumption of these fuels.

It is also evident that the consumption of Diesel fuel by private transport is higher than that consumed by trucks. This characteristic is due to the large number of private Diesel engine 4-wheel drive vehicles in use.

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ANNEX 1.1 WATER SUPPLY IN THE URBAN CENTRES

Djibouti ville, the principal urban center, is serviced by 26 wells with an average depth of 40 meters each and a capacity of 25,000 m3. This is distributed through a network 157 km long which is sufficient except for the Balbala low income housing district. Balbala's needs are met cost free from public fountains. The city network supplies energy to the submersible pumps.

Arta and Oueah, towns near Djibouti-City, are fed by two wells located in Oueah. The power for these wells is supplied by Djibouti-City.

Ali Sabieh receives its water supply from three wells located in Mouloud. These supply the needs of the agricultural cooperatives, the population and the livestock. Two 165 kVa generators give power to both the submerged pumps and to the village of Mouloud.

Dikhil is served by a natural spring and two deep wells (100 m). Ethiopian refugees (about 13,000) are supplied by a few local fountains and tank trucks.

Tadjourah in the north has three wells of which one has a water quality problem. The wells are powered off a grid; total head is 100 meters.

Obock is equipped with two wells with an average total head of 100 meters. Electricity is supplied by two generators of 50 kVa and 32 kVa.

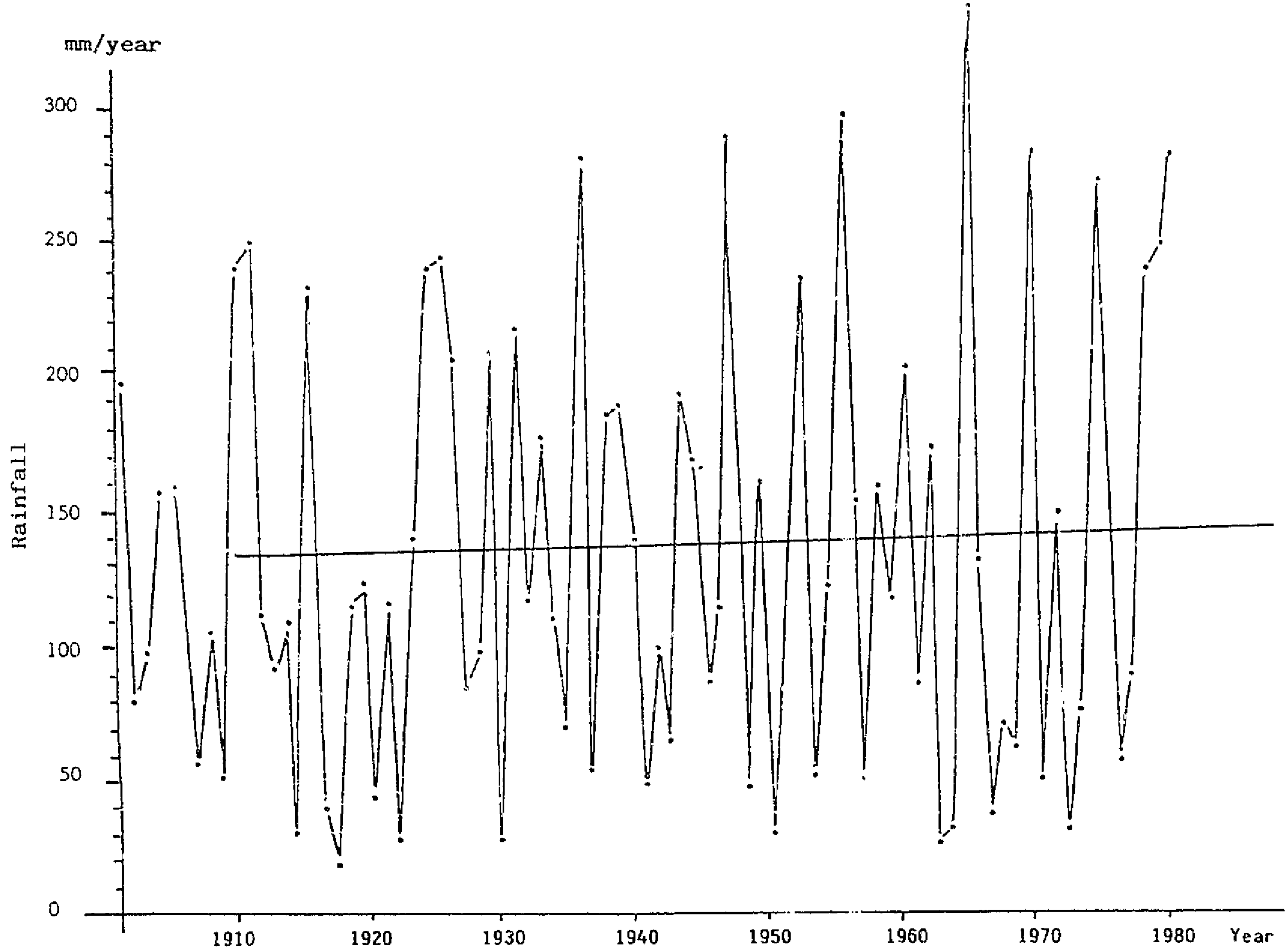

Table A1.1 Variation in Annual rainfall (Djibouti ville)

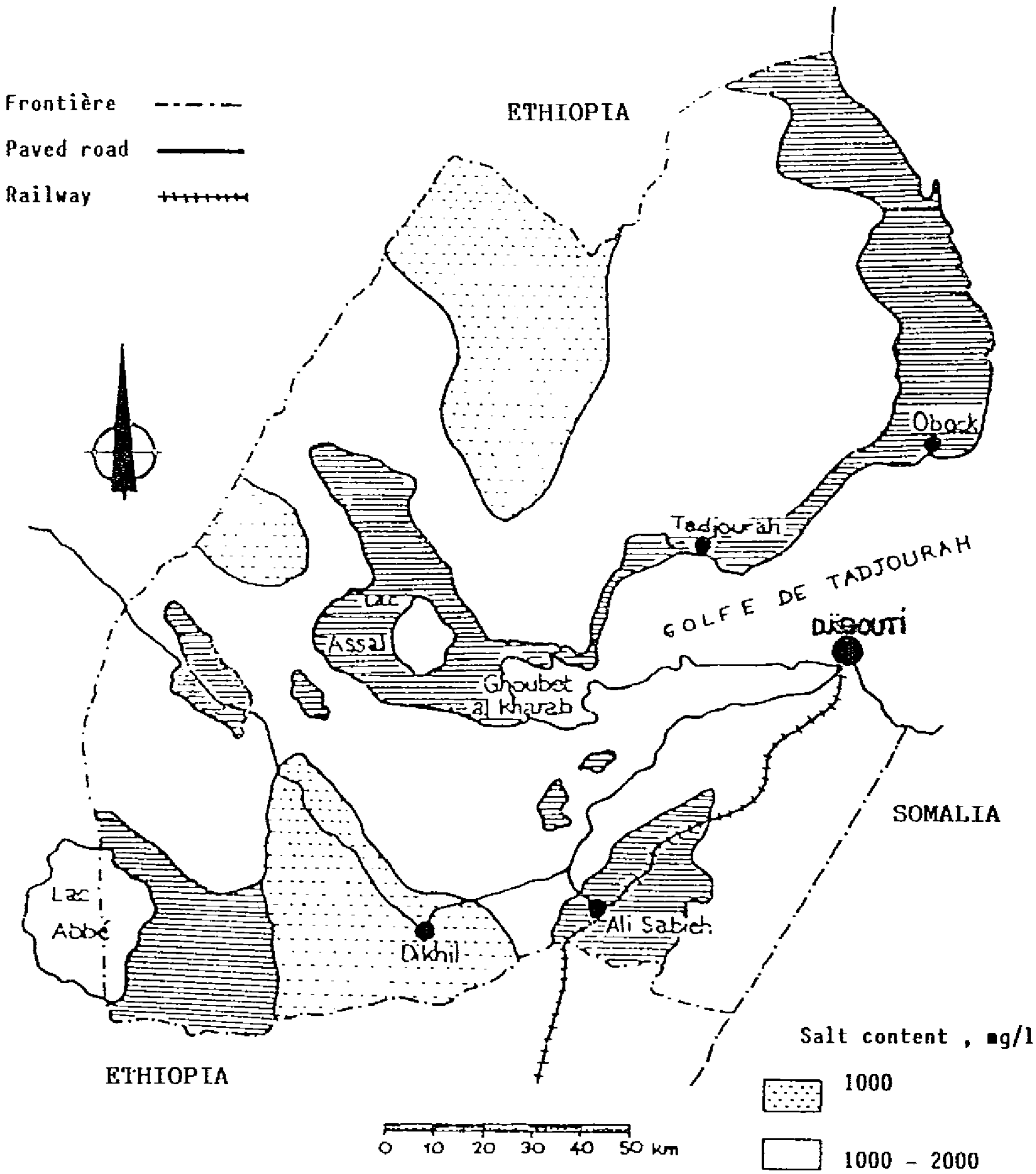

Figure A1.1 Quality of Subsurface Aquifers

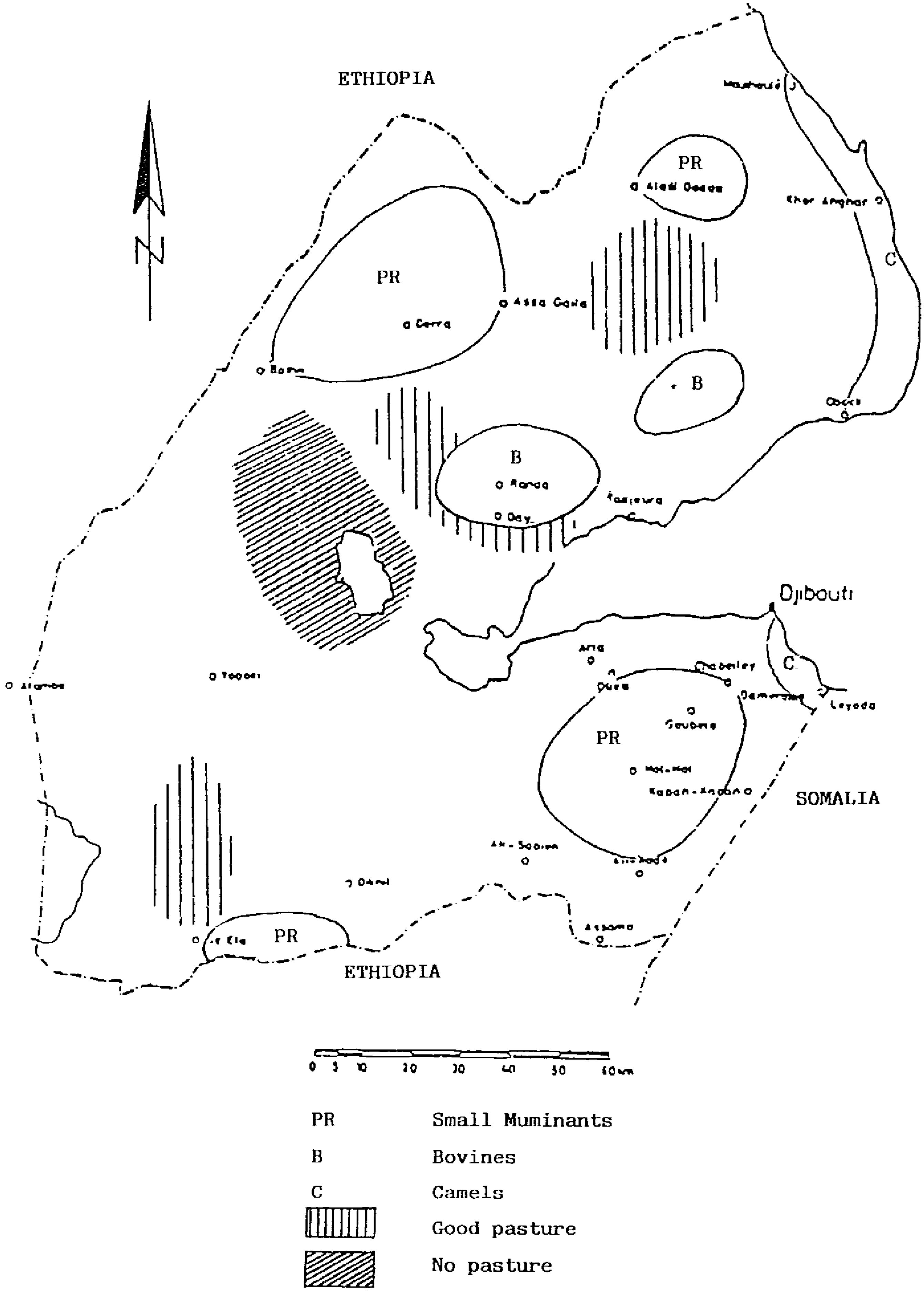

Figure A1.2 Distribution of Livestock in Djibouti

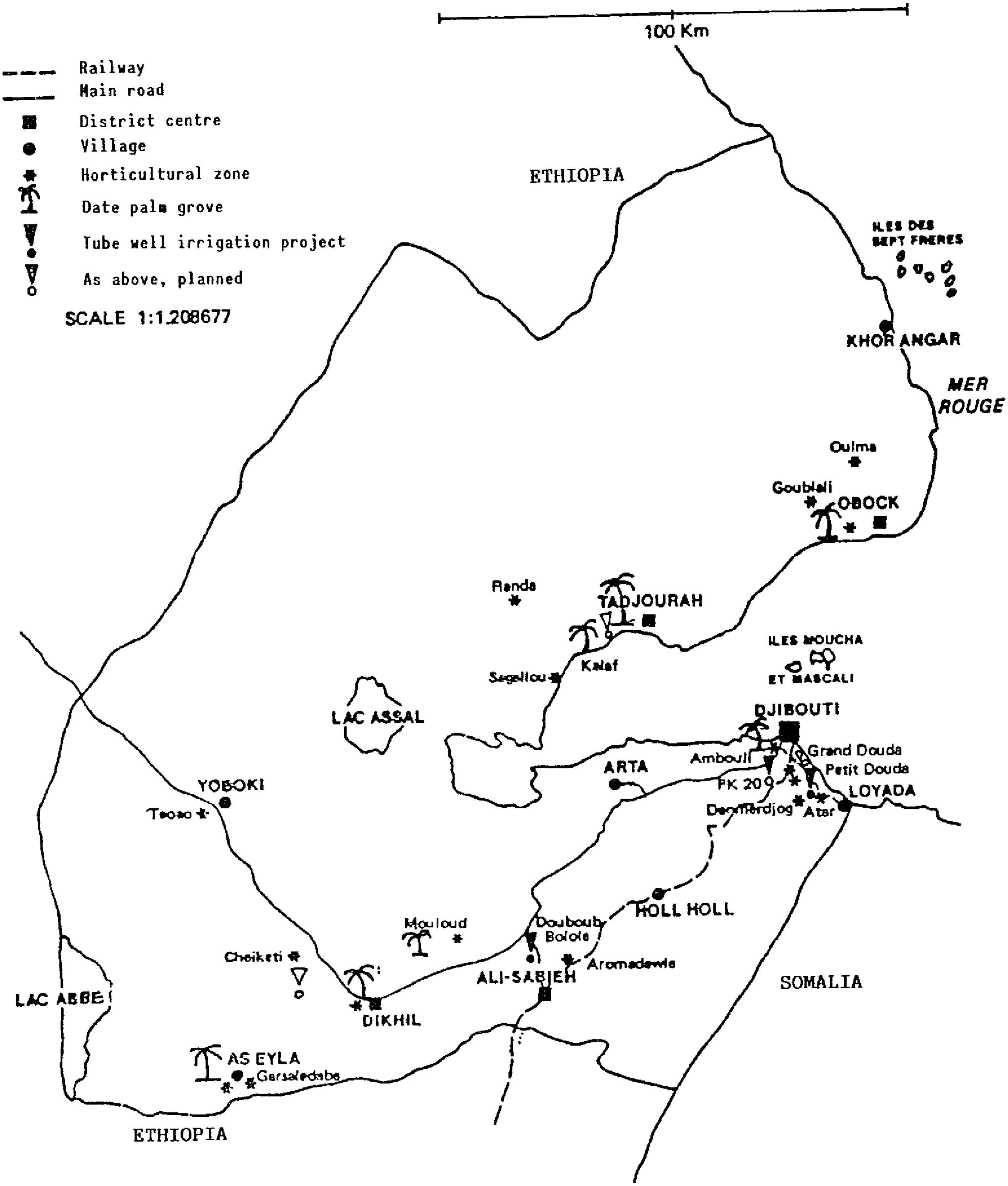

Figure A1.3 Agricultural Activities in Djibouti

ANNEX 1.2 DINAS SURVEY OF HOUSEHOLD ENERGY CONSUMPTION

During 1986, DINAS (the National Bureau of Statistics) conducted a detailed survey of household energy consumption in Djibouti ville .

The survey , which was carried out on a representative sample of 432 households, concerned only Djiboutian households, i.e it excluded families of military personnel and of other expatriates.

The households, 16 to a group, were located in 27 zones of study carefully selected on the basis of criteria such as income-level, type of housing, and the weight of the zone in the total population of Djibouti ville.

The energy consumption in each household was measured 3 times over a period of several months. The first survey conducted was an inventory of household appliances and fixtures. The second and third surveys focused on the different types of household consumption : food, leisure, energy etc.

Each day for a week, an analyst came to each household to weigh, estimate or calculate the different types of consumption.

With the help of DINAS, ISERST introduced into the questionnaire several pages of questions concerning energy consumption. The questions focus on :

- the structure of the building (in order to evaluate the thermal characteristics)

- the electrical appliances and fixtures (lighting, fans, air conditioner, refrigerators, etc)

- the method of cooking and the fuels used (LPG, kerosene, wood etc)

- recent energy bills.

The processing of the data obtained in the survey generated essential information the structure and level of energy use in the residential sector - a sector which previously was poorly understood from an energy point of view.

The principal results of the survey are presented in section 1.1 of this report. In particular, the survey clearly showed the difference between the official number of EdD subscriber in Djibouti ville, 16,500, and the number of households which were counted as having electicity: 21,300.

The difference is partly due to a significant amount of fraud-either by illegal hookups, unauthorized sharing of the supply, or modification of the subscribed power.

ANNEX 1.3 ISERST SURVEY IN THE DISTRICTS

In parallel with the survey carried out by DINAS in Djibouti ville, ISERST conducted a survey of energy consumption in the districts.

The survey (1986) was carried out on a sample of 50 households in seven towns : Obock, Tadjourah, Yoboki, Dikhil, Ali-Sabieh, Hol Hol and Arta. As far as possible households were representative of the local population.

The questionnaire used in the survey is presented overleaf. The principal results of the survey are presented in section 1.1 of this report.

I.S.E.R.S.T
BP 486
Djibouti

PLAN ENERGETIQUE NATIONAL

Enquête préalable sur la consommation énergétique des ménages dans les cercles de l'Intérieur

---

Date de l'enquête : / / 19

Localité : **Quartier :**

Nom de l'enquêteur :

Nombre de personne dans le ménage :

A) CUISINE

La cuisine est faite principalement:

____ au bois
____ au kérosène
____ au charbon de bois
____ autre: ____________

A.1) Cuisine au bois

- Type de foyer ____ 3 pierres ____ acheté ____ prix
  ____ autre ____ récolté
- Consommation ____ kg/semaine

Trouvez-vous facilement du bois? ____ oui ____ non

A.2) Cuisine au kérosène

- type de réchaud
  ____ simple foyer
  ____ double foyer
  ____ autre
- Consommation ____ litre/semaine

A.3) Charbon de bois

- type de réchaud ________________
- consommation ____ kg/semaine

A.4) Autre

- type de réchaud /foyer ________________
- consommation ________ /semaine

Utilisez-vous d'autres combustibles pour d'autres usages ?

____ aucun ____ bois ____ charbon de bois
____ kérosène ____ autre: ____________________

pour: ____ cérémonie religieuse ____ fête
____ autre: ________________________

Si vous utilisez du charbon de bois, quelle est sa provence ?

B) <u>ELECTRICITE</u>

Le logement dispose-t-il de l'électricité: ___ oui
___ non

<u>Si oui</u>

B.1) Puissance souscrite: ________ kVA

B.2) Dernière facture EdD:

Mois										
Montant										

B.3) <u>Equipement électrique</u>

Type		Nombre
Réfrigérateur	Petite taille	
	Grande taille	
Eclairage	Incandescent	
	Fluorescent	
Ventilateur	de plafond	
	mural/sur pied	
Climatiseur		
TV		
Radio		

<u>Si non</u>: Mode d'éclairage ____________________

C) EAU

Comment l'eau arrive-t-elle au logement ? ____ réseau

____ tuyau

____ sceau

____ autre

C.1) Pour le réseau ou les tuyaux

Nombre de points d'eau ____

Consommation journalière ____ litres

C.2) Pour les autres cas

Distance au point d'eau ____ mètres

Nombre trajets/jour ____

Consommation journalière ____ litres

D) BATIMENT

D.1) Toiture

___ béton
___ tole
___ autre: ________________

D.2) Faux plafond

___ aucun
___ non ventilé
___ ventilé

D.3) Murs

___ (béton, parpaing)
___ pierre
___ terre
___ tole
___ bois
___ autre: ________________

D.4) Fenêtre

___ volet imperméable à l'air
___ volet perméable à l'air
___ rideaux
___ vitrage

D.5) Sol

___ terre
___ béton
___ carrelage
___ autre: ________________

D.6) Ventilation

Le logement est-il doté de bouches de ventilation:

___ aucune
___ basse nombre: _____
___ haute nombre: _____

D.7) Protection solaire

Existe-t-il une bonne protection solaire du logement: ___ oui
___ non

Si oui: Quelle type de protection:

___ arbre ___ cannisse

___ avancée de toiture ___ autre: ________________

_HAPTER 2

THE ENERGY BALANCE FOR 1985

Tables 2.1 and 2.2 present the national energy balance and the disposition of final energy for the year 1985. These balances were developed as a part of the analysis conducted for the implementation of the MEDEE-S computer model.

The main points illustrated by the energy balances can be summarized as follows:

a) Energy produced from national resources accounts for only 13 % of the total energy consumed in the country. The remainder is imported, and is almost entirely petroleum products.

b) Losses due to conversion and distribution account for 28 % of the energy consumed. The efficiency of the energy sector in Djibouti is therefore approximately 72 %.

c) The losses due to the generation of electricity account for 80 % of the overall losses. The remainder is due to the production of charcoal (7.8 %), and losses due to the transmission and distribution of electricity (12.2 %).

d) The final consumption of energy in 1985 amounted to almost 71,300 TPE which represents a per capita energy consumption of 0.166 TPE. The energy intensity per unit of Gross Domestic Product was 1.18 TPE per million FD.

e) The figures below present the relative weight of each sector in the final consumption of energy.

Agriculture and fishing	0.3 %
Industry and construction	5.0 %
Transportation	39.8 %
Services	17.6 %
Residential	37.3 %

f) The structure of the consumption by energy type is as follows:

Wood and charcoal	15.5 %
Hydrocarbon fuels	67.6 %
Electricity	16.9 %

TABLE 2.1

ENERGY BALANCE FOR THE REPUBLIQUE OF DJIBOUTI

YEAR : 1985	PRIMARY ENERGY					SECONDARY ENERGY									
TEP	Wood	Oil	Geotherm.	Solar	TOTAL PRIMARY ENERGY	Charcoal	LPG	Gasoline	Jet fuel	Kerosene	Diesel	Fuel oil	TOTAL HYDROCARB.	Electricity	TOTAL
PRODUCTION	13135				13135								0		13135
IMPORTS					0	50	658	9384	62271	9510	64521	93134	239478		239528
EXPORTS					0				-57608		-40472	-56257	-154337		-154337
TRANSFERS					0				-116		116		0		0
STOCK CHANGES					0		-30	1408		586	1701	-2926	739		739
TOTAL NATIONAL MARKET	13135	0	0	0	13135	50	628	10792	4547	10096	25866	33951	85880	0	99065
ELECTRICITY GENERATION					0						-3030	-33430	-36460	14125	-22335
PETROLEUM REFINING					0								0		0
CHARCOAL PRODUCTION	-2960				-2960	792							0		-2168
STORAGE, DISTRIBUTION LOSSES							-5	-179	-41		-411	-521	-1157	-2107	-3264
FINAL CONSUMPTION	10175	0	0	0	10175	842	623	10613	4506	10096	22425	0	48263	12018	71298
AGRICULTURE AND FISHING											113		113	76	189
INDUSTRY AND CONSTRUCTION											3161		3161	436	3597
TRANSPORTATION								7603	4492		16298		28393		28393
SERVICES							71	640		659	1880		3250	3815	7065
RESIDENTIAL	10175					842	420			9437			9857	5667	26541
FRENCH ARMY							132	2370	14		973		3489	2024	5513
STATISTICAL ADJUSTMENTS															

TABLE 2.2 ENERGY BALANCE FOR THE FINAL CONSUMPTION OF ENERGY

YEAR: 1985 TEP	BIOMASS Wood	Charcoal	TOTAL BIOMASS	HYDROCARBON FUELS LPG	Gasoline	Jet fuel	Kerosene	Diesel	Fuel oil	TOTAL HYDROCARBS.	Electricity	TOTAL
AGRICULTURE AND FISHING								113		113	76	189
INDUSTRY AND CONSTRUCTION								3161		3161	436	3597
TRANSPORTATION					7603	4492		16298		28393		28393
- AIR						4492				4492		4492
- ROAD								6279		6279		6279
- INDIVIDUAL					7475			8147		15622		15622
- RAILWAY								1306		1306		1306
- MARITIME					128			566		694		694
SERVICES				71	640		659	1880		3250	3815	7065
- ADMIN., PUBLIC SERVICES					640		49	1880		2569	1975	4544
- COMMERCE AND BANKS											660	660
- HOTELS, BARS, RESTAURANTS				71			610			681	617	1298
- PUBLIC LIGHTING											155	155
- WATER PUMPING											408	408
RESIDENTIAL	10175	842	11017	420			9437			9857	5667	26541
SUB TOTAL	10175	842	11017	491	8243	4492	10096	21452		44774	9994	65765
FRENCH ARMY				132	2370	14		973		3489	2024	5513
TOTAL	10175	842	11017	623	10613	4506	10096	22425		48263	12018	71298

CHAPTER 3

PRIMARY ENERGY

3.1. FUELWOOD

3.1.1. Potential Resources

Adequate data on fuelwood resources are not available because the Republic of Djibouti does not possess the means to fully study the resource base.

The sole forestry projects completed or in progress concern the Day forest, which is not representative of the vegetation of Djibouti.

There is no inventory of forest resources, and the natural production of the country's various forest stands is not known. It is therefore impossible to assess the current availability of this resource with any precision /3.1/.

3.1.2. The Use of Wood

Wood is widely used by rural populations for household uses such as:

- cooking food
- producing charcoal for the urban areas
- building the traditional shelter, the "taboita" (a hemispherical hut covered with matting)
- fencing off gardens or other enclosures.

Generally, only dead wood is collected. Among the Afars, custom forbids the cutting of live wood, and imposes a penalty of 12 goats for such an infraction. This respect for the environment stems from the Afars' tribal system of land ownership.

In the southern regions between the coast and Ali- Sabieh, the cutting of wood seems now to have become a more common practice. According to one FAO expert, it would appear that along Djibouti's coastal plain south of the capital the felling of live trees has become a habit, whereas tradition used to require a meeting of the Council in order to obtain the agreement of the tribe /3.2/.

Besides the use of fuelwood for cooking and making charcoal, the other major use of wood is for grazing. In fact, specialists believe that overgrazing around the villages and around the wells and other sources of water is the main cause of the degradation of the natural stands, particularly because it prevents spontaneous regeneration.

Data collected in the field seem to indicate that in areas of high firewood consumption adequate supplies of dead wood remain, but no one can say for how long. In some areas around rural centers with a high population density (e.g., Randa, As-Eyla, Yoboki), dead wood for local use must now be collected from farther and farther away (4 to 10 km or more).

By contrast, in areas of low population density, where the majority of the population is nomadic, the availability of dead wood does not seem to present a problem.

According to an expert participating in a livestock breeding project in an extensive area around Dorra, dead wood is under-utilized in this region.

In general, the exploitation of the resource consists of simply gathering dead wood strewn on the ground, or of cutting up dead trees, either those still standing or those uprooted by the khamsin (the hot summer wind) or by the flooding of the wadis.

Wood for personal use is collected by women, maids, or children within distances which may range from several hundred meters to 5-6 km depending on the circumstances. Wood is gathered rather than cut; the pieces collected for use as firewood are small in diameter (2 to 8 cm).

The wood sold beside the roads or trails may come from the surplus gathered by the women living in nearby camps (thereby providing them with a cash income), or from the cutting of wood and dead trees by sedentary nomads for whom such exploitation has become one of their activities. Such men may also work as woodcutters and charcoal-makers.

Camel-driving nomads may also collect wood for sale or barter. Gathering and cutting dead wood has become an economic activity for a sizable number of rural people with no other source of income.

In the nomadic populations, or in sedentary camps of low population density, wood is never purchased. The wood is collected from the area surrounding the camp by a member of the family--usually women or children. Migrating nomads gather their wood where they stop, depending on their route.

In sedentary rural populations of high density, wood is either collected from the surrounding area by the women and children, or purchased directly from camel- or ass-drivers who gather wood over long distances (often more than 10 km). The latter mode of supply occurs chiefly in the rural centres, such as As-Eyla or Yoboki, where adequate supplies of wood can no longer be found nearby. It is common for nomads to gather dead wood for barter.

In these areas, finding, gathering, and transporting wood often requires an entire day (and often more in Yoboki). The wood is sold directly to families by the camel-load, the half camel-load, or an ass-load.

In the District capitals, wood is little used except in Tadjourah, where it is still the most commonly used fuel. The supply patterns of this region are discussed below.

Very few families collect their own wood. Most buy it directly from camel- or ass-drivers or in the wood markets. Wood is generally transported in light trucks (rarely by camel), then sold in the markets.

The wood comes from nearby natural stands (forests or wadis), where the carriers purchase it directly from the cutters or gatherers along the roads or trails. In Tadjourah, wood comes chiefly from the region of Sagallou and Kalaf, as well as from wadis located along the road to Randa.

The carrier sells wood to merchants who store it for resale to consumers. It is generally carriers returning empty who take on loads of wood as return freight. In Tadjourah, merchants transport a large portion of their stock to Djibouti in dhows.

Wood is sold by the bundle. The average weight of a bundle has been estimated at 11.8 kg, based on 130 weighings at various points (on the roadside, the port at Tadjourah, the Salines market in Djibouti ville).

In Djibouti ville, the trade in wood and charcoal is not structured. The main market for wood is the Salines market.

Most of the wood which the supplies the markets of Djibouti comes from the Tadjourah region. The wood is stored in the port of Tadjourah before being transported on dhows. When it arrives at L'Escale, the wood is carried to the markets on carts drawn by asses.

Deals are struck between the merchants of Tadjourah and those of Djibouti. The cost of transportation by dhow and cart is paid by the merchant and depends on the number of bundles carried.

The carriers are therefore not intermediary purchasers. Carting fees are approximately 50 FD per bundle--about 1,000 FD per cartload.

Over a period of two weeks at the end of August, 1986, the quantities of wood and charcoal arriving at the port in dhows from the north were recorded. These arrivals, and the amounts transported, are not regular. During this period, 1,342 bundles of wood weighing approximately 16 metric tons entered Djibouti ville via this route.

A two-week record is not sufficient to make an accurate determination of the quantities entering the town of Djibouti annually, but it gives an idea of the amounts involved.

Records compiled over month-long periods in different seasons should be made.

In Djibouti ville, one also sees women carrying bundles of wood on their backs which has been gathered at the city limits, or even within the city. The wood is usually for household use, although sometimes it is sold (e.g., to restaurants). However, the quantities involved are not large. In outlying areas of the city, small quantities of wood are gathered directly for personal consumption.

The total annual consumption of fuelwood used for cooking in Djibouti, which is discussed in greater detail in Chapter 1, is estimated at 10,175 TPE, or 13,135 TPE if one adds the wood used in the manufacture of charcoal. The latter figure is the equivalent of about 35,000 tonnes of wood.

From data collected in the Districts by local authorities, rural development technicians, various pastoral projects, and the population, it seems that for the great majority of those who depend on it, the availability of fuelwood is not a problem. The populations involved do not feel that they are affected by any particular crisis.

Will supplies of dead wood remain adequate to meet the future demand for fuelwood? This is a question which remains to be answered. However, until a study of the forest resource base can be carried out, that answer will not be forthcoming.

With respect to the low-density nomadic and rural populations, the supply of fuelwood is not a problem. Because these populations are widely scattered the exploitation of the resource is spread widely, and supplies of dead wood remain greater than the demand.

In the towns in the rural areas, and especially in the District administrative centres, the demand for wood is more concentrated, and dead wood is gradually becoming scarce in the surrounding areas. The resource is disappearing around the population centers, and the distances which must be travelled in order to find wood are progressively increasing. These are the areas that should have priority in the event of future wood conservation efforts.

As a point of information, one might note that 35,000 tonnes of wood per year is generally considered equivalent to the natural production of approximately 90,000 hectares of forested area. However, this figure would certainly not hold for Djibouti, since the natural stands are of different species, and overgrazing severely impedes natural regeneration. The above figure is provided solely as an indication of the order of magnitude.

From another point of view, if one considers that a typical tree such as the acacia has a dry ligneous mass of approximately 80 kg, 35,000 tonnes of wood is equivalent to about 440,000 dead trees of this type.

3.1.3. Economic Aspects

In contrast to the situation in most African countries, the resource is initially free. The wood seller or charcoal producer pays no tax (in the form of a cutting permit for instance).

On the market, wood is generally sold by the bundle (at an average weight of 11.8 kg). However, bundles are found in varying sizes in Dikhil (5-6 kg) and As-Eyla (20 kg or more). In the rural centers, wood is sold by the camel-load or the ass-load.

A camel-load is estimated to be between 100 and 180 kg, and an ass-load between 40 and 60 kg.

The price of wood is fairly stable throughout the year, as opposed to the price of charcoal, which fluctuates. The latter fuel is less costly in the hot season when the demand is lower.

Table 3.1.1 Average Price of Fuelwood in Djibouti, FD

	price per bundle	price of larger volumes	price per kilogram
District of Tadjourah			
- road side	100		8.4
- Tadjourah after transportation	120-130		10.6
- Tadjourah market	150	camel load 1200-1500	12.7
District of Dikhil			
- road side	100		8.4
- As-Eyla	100	camel 1500 ass 500	8.4
- Dikhil	150-200		12.5-17
Obock	100		8.4
Djibouti			
- Salines market	300		25.4
- Avenue 26			
- Retail sale			

In this table, a typical bundle weighs 11.8 kg.

The kilogram prices indicated in the preceding table are only approximate and should be considered as such.

In general, it is very difficult to obtain accurate data from the various participants in the supply network concerning purchase prices, the quantities involved, and the mode of provision. One often obtains contradictory information.

3.2. SOLAR ENERGY

3.2.1. Resource Potential

Solar energy is an important energy resource for Djibouti for several reasons:

- levels of sunlight are among the highest in the world and remain relatively constant throughout the year.

- under conditions such as those present in Djibouti, a number of solar energy technologies are already economically competitive with conventional oil-based technologies.

- solar energy is available in all regions of the country, and is therefore a particularly appropriate resource for rural areas that possess no other local energy resource.

Solar energy potential is measured and calculated based on the intensity of the insolation on a horizontal surface. These values vary widely at different points on the globe, depending on latitude, local climatic conditions, the elevation of the site, and other factors. Insolation levels range from very low levels (less than 1,500 MJ/m2.year at the poles) to values that may reach more than 9,000 MJ/m2.year in the most favorable parts of the world.

With average levels of insolation of 7,800 MJ/m2.year, Djibouti enjoys very sizable solar energy resources. Each year, the country receives the solar energy equivalent of 4 billion TPE, an amount of energy 40 thousand times greater than the country's current level of energy consumption.

Table 3.2.1. shows monthly average levels of daily global insolation measured during 1983 and 1984 by instruments installed by ISERST.

For the country as a whole, the mean daily insolation is 21.4 MJ/m2.day. Different regions show average values between 19.1 and 23.4 MJ/m2.day. There is some seasonal variation, but it is not pronounced.

Djibouti's solar energy resources are extremely reliable in comparison with many other areas of the world. Cloudy conditions and rain are very infrequent.

Table 3.2.1 Solar Radiation in Djibouti, MJ/m2.day

Locality	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	mean
Ali Sabieh	1983		16.2	18.0	22.0	23.4	22.7	22.0	21.2	23.0	23.0	23.4	21.6	21.6
	1984	21.6	22.7	24.8	26.3	23.4	21.6	20.2	21.2	22.3	23.0	19.8	15.8	22.0
Dikhil	1983		22.7	22.0	22.7	22.3	23.8	23.0	23.8	23.4	23.8	22.0	20.5	22.7
	1984	20.2	23.0	24.5	25.6	23.4	24.1	22.7	24.1	24.1	25.9	23.0	21.2	23.4
Djibouti-ville	1983		14.8	20.9	22.0	22.7	22.0	21.2	23.0	23.0	22.7	22.0	21.2	21.2
	1984	21.6	22.3	24.5	26.3	23.0	22.0	22.0	24.1	21.6	24.8	23.4	20.2	23.0
Hol Hol	1983					18.4	20.2	20.2	20.2	19.8	20.9	19.1	15.8	19.4
	1984						22.0	20.9	22.0	22.3	20.5	19.8	19.1	20.9
Obock	1983		16.6	20.5	22.3	23.0	22.3	20.2	19.1	21.6	22.0	20.9	19.4	20.5
	1984	18.4	22.0	23.4	24.8	23.4	22.7	21.2	23.4	22.3				22.3
Tadjourah	1983						21.2	19.4	18.7	21.2	20.5	18.7	17.6	19.1
	1984	16.9	20.5	22.3	24.1	20.9	20.9	19.1	22.3	21.2		19.8	17.3	20.5
Yoboki	1983					20.5	22.0	20.9	20.5	22.0	22.0	20.9	19.1	20.9
	1984	19.1	22.0	23.4	24.1	22.0	21.6	20.2	22.3	20.5	23.8	20.5	18.7	21.6

3.2.2. Present Use of Solar Energy

Photovoltaic systems are the subject of considerable interest in Djibouti, chiefly for pumping water, for communications, and for conserving refrigerated vaccines in rural clinics.

The installed photovoltaic capacity in the country is approximately 12 kW peak. The largest system is installed on the renewable energy building of ISERST in Djibouti ville. This 5.3 kW peak system powers the fluorescent lighting, ceiling fans, and the office equipment in the building. From October to May, the building is supplied with electricity entirely by the photovoltaic system.

The facilities of RTD (Djibouti Radio and Television) in Ali-Sabieh are also equipped with a photovoltaic system. This installation uses German modules (AG Telefunken) and has an effective capacity of 600 watts. The power produced by these modules supplies the Arta FM radio relay and the transmitter for the Ali-Sabieh region.

In addition, a 2.6 kW solar energy pumping station is running in an experimental garden in Attar, south of Djibouti ville. The system does not perform the primary pumping, but pumps 100 to 150 m3 of water per day from a holding tank into drip irrigation channels supplying individual gardens.

One of the most promising examples of the use of solar energy is the pumping of water using solar pumps. In Djibouti there are now approximately 10 photovoltaic pumps installed in wells located in rural areas and used for the irrigation of small garden plots.

Generally small (300-400 watts peak), these systems use either floating pumps (SEI, AEG, and TED brands) or surface pumps (AY McDonald brand).

Another important installation is the 480 watt ARCO photovoltaic system used in Djibouti's vocational school (the lycée d'enseignement professionnel). This system is used by the school's science classes to power laboratory equipment, and for courses dealing with direct current and photovoltaic technology.

Other equipment powered by photovoltaic energy can be found in Djibouti. The German army is participating in a program designed to train and equip the police, and has supplied photovoltaic emergency systems for a part of the country's police radio network. An 80 watt/24 volt AG Telefunken system was purchased to provide for the permanent operation of these radios. Ninety 20-watt panels have been installed for the radios used in rural areas. In addition, photovoltaic modules are installed on top of watertowers in Djibouti ville. These panels provide power to instruments which monitor the water level in the towers.

Solar refrigeration technology holds a good deal of interest for the Ministry of Health since many dispensaries in the rural areas do not have electricity. A refrigerator powered by a photovoltaic system can be used to conserve vaccines or to make ice for use in transporting the vaccines to more distant areas. ISERST has recently installed the first such system in the dispensary at Hol Hol. The system also supplies power for several fluorescent lights in the building.

There are few solar heating systems in Djibouti. Their use in the housing sector is not widespread since water temperatures are naturally rather high. However, a number of firms in the industrial sector require large quantities of hot water for their manufacturing processes. In these cases, it may be advantageous to install solar collectors.

3.2.3. Future Uses of Solar Energy

Solar energy can be used to produce all of the principal forms of power: thermal, electrical, and mechanical.

These forms are interchangeable (although energy conversion always entails losses), and the technology needed to convert one form of energy into another is well known and widespread. Most of these technologies are too expensive to be competitive with conventional energy technology. However, a number of solar technologies are economical, or very nearly so, and should be considered as possible options for Djibouti.

Several of these technologies are described below.

3.2.3.1. Photovoltaic Pumps

As mentioned above, there are several photovoltaic pumps in operation in Djibouti. The reliability of these systems, and particularly of the solar panels which are their most expensive component, has been clearly demonstrated.

The water needs in the rural areas of Djibouti are of primary importance, and solar pumps are a technology that works well in these zones. They are economically competitive with other pumping technologies (e.g. wind- powered and motorized pumps) under certain conditions which will be discussed in Chapter 9.

3.2.3.2. Refrigeration

Photovoltaic panels can be used to supply direct current to 12-volt DC refrigerators. A number of systems have been installed in other developing countries and the results have been encouraging /3.4/. The systems are reliable and require very little maintenance or supervision. The cost of a solar refrigeration system is about $4,000--several times more expensive than conventional electric refrigerators or units that operate on kerosene or natural gas.

However, the greater reliability of the photovoltaic units, the minimal maintenance they require, and the possibility of connecting additional electrical equipment to the photovoltaic system make solar refrigerators an important technology for rural dispensaries and vaccination centers that do not have electricity, or that are supplied only intermittently by the power utility.

3.2.3.3. Air Conditioning

Solar thermal energy may also be used to drive absorption chillers in order to produce cold water for air conditioning. Such systems are typically central units which provide air conditioning for large buildings. Prototype systems have been installed in several locations in the United States and in other countries.

However, absorption chillers powered by solar energy are complicated systems that require the presence of specialized technicians if the units are to operate without problems. They are also costly because of their very low efficiency, and thus cannot be considered appropriate for Djibouti at the present time.

3.2.3.4. Thermal Production of Electricity

Solar power plants are designed to transfer concentrated solar energy to a heat transfer fluid which drives a Rankine cycle thermodynamic system generating electric power.

Central receiver ("power tower") systems consist of a tower supporting an absorber that is heated by direct solar radiation reflected on to the absorber by a field of heliostats. Thermal energy is transferred from the absorber by a heat transfer fluid which in turn becomes the heat source in a thermodynamic cycle that produces electricity.

Other types of solar power plants make use of parabolic reflectors. Direct sunlight is focused on an absorber through which flows a heat transfer fluid.

There are 2 principal types of solar power plants using parabolic collectors:

- systems using hemispherical parabolic solar collectors focus sunlight on to a cavity absorber positioned at the focal point of the parabolic dish.

- systems using linear parabolic solar collectors concentrate sunlight on to an absorber pipe positioned along the linear focus of the parabolic trough.

Solar power plants using flat plate solar collectors are also technically feasible, but these are not cost-effective for the production of electricity.

A number of solar power plants are operating in the industrial countries (e.g. in France, the United States, Spain, Japan, and the USSR). The largest system is the SEGS II plant in southern California, which produces 30 MW peak. Although such plants are not yet cost-effective, the cost of installation is dropping steadily.

For example, the cost of SOLAR ONE, one of the first solar power plants built in the United States in 1981, was approximately $14,000/kW peak. SEGS II, built in 1985, cost $3,100/kW, and it is believed that the cost of similar plants now under construction will be about $2,000/kW.

As soon as costs fall to these levels, solar power plants may become a cost-effective option for Djibouti /3-3/.

The technical and economic development of solar power plants in the industrialized countries should be closely monitored by Djibouti's researchers.

3.2.3.5 Photovoltaic Power Generation

Photovoltaic panels can be mounted on heliostats which, connected together, can generate electricity at the megawatt level.

The largest installation of this type is in southern California generating over 5 MW peak.

The cost of producing electricity in photovoltaic power plants remains much higher than that of electricity produced using conventional technology, including geothermal power. Nevertheless, the cost of photovoltaic electricity is falling, and it would be prudent to periodically review this technology, and to compare the reported cost of PV power with the cost of electricity being produced in Djibouti.

3.2.4. Economic Aspects

As mentioned earlier, many solar technologies are too costly to be considered as alternatives to the more conventional technologies based on petroleum.

The photovoltaic technologies which are the most economic at the present time are photovoltaic communications systems and PV refrigerators. Solar pumps are competitive, but are generally less economical than windmill pumps, except where water needs are low. This aspect is examined in greater detail in section 9.1.2.1. and in annex 9.3.

However, the price of photovoltaic cells continues to fall steadily, and a selling price of $2 per peak watt (1985 dollars), or about a third of the current price, is almost certain to be reached by the end of the decade.

3.3. WIND POWER

3.3.1. Resource Potential

In addition to solar energy, another renewable energy resource is readily available in Djibouti: wind power.

In general, average wind speed must be at least 2.5 m/s for water pumping, and at least 5 m/s if wind is to economically generate electricity.

During 1983-84, average wind speeds in Djibouti were measured at almost exactly 4 m/s. Furthermore, mean windspeeds at this level suggest that there are regions where the wind may be adequate for the production of electricity using wind turbines at a cost comparable with that of photovoltaic systems and small Diesel generators.

Table 3.3.1. shows monthly average wind speeds for seven regions in Djibouti, measured by ISERST during 1983-84.

From this table, it is clear that average windspeeds in most of the districts of Djibouti are sufficient to power windmill pumps. Only the areas around Hol Hol show an average wind speed of less than 3.5 m/s

The region that stretches southeast of Yoboki to Dikhil and to Ali Sabieh shows an average annual wind speed of more than 4 m/s. Only in Tadjourah is the wind speed higher, but it is suspected that these data are erroneous, and are not representative of the windspeeds in this region.

Seasonal variations are significant and vary widely with the site. Ali Sabieh and Dikhil consistently show windspeeds lower than the annual mean between May and September. The same tendency exists at Yoboki. The other regions show the influence of the khamsin, which blows from the west during July and August.

These windspeeds confirm that windmills are a viable option for water pumping in Djibouti. It should also be noted that windmills can lift water from depths as great as 200 metres.

Table 3.3.1. Monthly Mean Windspeeds in Djibouti (m/s)

Locality	year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Ali Sabieh	1983		6.0	7.3	4.6	3.2	2.3	3.2	4.3	2.9	4.4	5.6	4.6	4.4
	1984	3.9	4.3	4.0	3.7	2.7	3.0	3.4	2.9	3.4	4.4	5.1	4.7	3.7
Dikhil	1983		5.4	5.9	4.8	3.8	2.4	2.6	3.1	3.0	5.4	5.8	5.1	5.2
	1984	4.5	5.7	6.6	5.7	3.5	3.6	3.0	2.6	3.2	5.6	5.8	5.2	4.5
Djibouti	1983		3.3	4.6	2.9	3.0	3.4	4.0	4.0	3.0	3.1	3.8	3.8	3.6
ville	1984	4.2	5.7	3.5	3.1	3.3	3.3	3.8	3.8	4.1	3.3	4.5	3.2	3.7
Hol Hol	1983											1.6	1.3	1.5
	1984	1.3	1.7	1.8	1.5	1.5	2.5	2.8	2.2	1.8	1.7	2.1	1.9	1.9
Obock	1983		3.4	4.1	3.0	2.8	3.2	5.0	5.3	3.6	3.4	3.3	4.0	3.8
	1984	3.3	3.2						4.6		4.2	3.8		3.8
Tadjourah	1983					3.2	2.9	4.0	4.8	5.6	6.4	6.9	6.6	5.1
	1984	7.0	6.9	7.6	6.8	6.5	7.9	7.8	6.5	7.5		7.5	5.7	7.1
Yoboki	1983						3.0	3.7	4.0	3.3	4.7	4.9	4.8	4.0
	1984	4.0	4.9	4.9	4.8	3.7	4.0	4.3	3.7	3.8	4.5	5.0	5.0	4.4

3.3.2. Present Use of Wind Energy

Windmill pumps have been used in Djibouti for more than 20 years. At the present time, there are 5 large windmills installed, as well as several smaller units. Table 3.3.2 shows the location, type, and operating condition of the windmills in Djibouti.

Table 3.3.2. Windmills in Djibouti

Site	Machine	Rotor diameter (m)	Comments
Obock	Aermotor	3.0	good condition, pumping
Ambouli	Aermotor	3.6	good condition, pumping
Aramadoule	Aermotor	3.6	good condition, pumping
Asa Geyla	Aermotor	3.6	good condition, pumping
Tadjourah	Humblot	4.0	out of service
Douda	Oasis	2.0	pumping from a small well with low output
Ali Addé	Alisé (2)	2.6	pumping from small wells
Hanlé	Pumpomat (2)	1.7	pumping from small wells

3.3.3. Future Use of Wind Energy

3.3.3.1. Pumping water

The results of the economic analysis of water pumping technology described in section 9.1.2.1. show that in those regions of Djibouti where the wind speed is greater than 4 m/s, wind-powered pumps are the most economical option for pumping water in wells of average depth. It is recommended that the use of windmill pumps be encouraged in Djibouti.

ISERST's technicians now have several years of experience in installing and servicing wind-powered pumps. If this knowledge and skill can be transferred to the technicians of the Genie Rural and to those of the Districts, the maintenance of wind-powered pumps in the rural areas should not pose serious problems.

3.3.3.2. Electric power

The use of wind to produce electricity is well developed in many countries. For example, in California in 1985 wind-power stations (wind farms) produced nearly 700 million kWh of electricity, about the same output as a conventional 100 MW power plant /3.5/.

Producing electricity from the wind at a cost that can compete with Diesel generators requires average wind speeds of at least 6 m/s. The meteorological data collected to date do not show such windspeeds, but measurements have not yet been taken at the most favorable sites (especially those on the northeast coast and in the mountains in the north).

One application of electricity produced from the wind is pumping water using an electric pump. This arrangement has one major advantage: the wind turbine may be located on the top of a hill for instance, where winds are usually stronger, while the pump itself is placed at the water source.

3.3.4. Economic Aspects

3.3.4.1. Water Pumping

The economic aspects of using windmills to pump water are examined in Chapter 9.1.2.1. Additional details can be found in annex 9.3.

3.3.4.2. Electric Power

The cost of the electric power produced by wind turbines is extremely sensitive to the wind characteristics at the proposed site. The most recent experience with wind-power stations in California indicates that electric power can be produced at a cost of 9 to 14 FD/kWh at sites where the average wind speed is approximately 7 meters per second /3-5/.

Assuming that the efficiency of wind turbines is independant of wind speed, and noting that the power of the wind varies with the cube of the windspeed, the cost of electricity at different windspeeds may be estimated as follows:

Windspeed (m/s)	Cost of electricity (FD/kWh)
4	48 - 75
5	24 - 38
6	14 - 22

Windspeed data collected by ISERST during 1983 and 1984, shown in Table 3.3.1, do not show average windspeeds greater than 4.5 m/s (excluding the data for Tadjourah, which are not considered reliable). However, it is certainly possible that sites with mean windspeeds greater than 6 m/s exist in Djibouti, and it would be useful to study the windspeeds in some of the more isolated regions of the country in greater detail.

It should be noted that the costs indicated above are based on US wind farms that are directly connected to the power distribution system. For units operating in isolated regions, accumulator batteries and inverters would be required, which would considerably increase the cost of the electricity produced.

3.4. GEOTHERMAL ENERGY

The highest concentrations of geothermal heat are found where the hot molten magma beneath the earth's surface exerts sufficient pressure to produce volcanic activity. Among the regions with the highest geothermal concentrations are those which, like the Republic of Djibouti, are situated above shifting faults in the earth's crust.

Within the territory of Djibouti, this is particularly true of the Afar Depression (also known as the Danakil Depression), which lies at the junction of three large tectonic structures: the Red Sea, the Gulf of Aden, and the East African Rift.

As a result, Djibouti possesses considerable geothermal resources which could play a major role in the future energy development of the country.

However, for a geothermal field to be fully exploited, high underground temperatures are a necessary but not a sufficient condition; there must also be a permeable rock structure through which water may circulate. When extracted through boreholes, the water makes it possible to transfer the geothermal heat of the subterranean rocks to the power generation systems on the surface.

Identifying geothermal fields where these basic conditions are met, and where operating facilities might be developed under suitable technical and economical conditions, involves a painstaking process of exploration, testing, and analysis -- a process that can be long and costly.

One of the principal objectives of the national energy policy is to develop Djibouti's geothermal resources. Explorations conducted by France prior to Independence, and later by Italy, have led the government to believe that it may be able to successfully develop this national energy resource.

To this end, the government has undertaken a program of exploratory drilling that is now in progress, and which is financed by a group of lenders led by the World Bank. The program is aimed at determining the possibility of exploiting Djibouti's geothermal resources in the most effective and economic manner.

The Assal zone, the Hanlé-Gaggadé region, and the Abbé Depression are the main areas of interest. A deep well previously drilled in the Assal zone confirmed the existence of geothermal resources, but found highly saline fluids that would make exploitation more difficult. However, in the other zones, the hydrogeological structures create conditions for the recharge of the geothermal system with sweeter water, thus improving the quality of the geothermal fluids.

The results of the scientific studies, together with certain logistical conditions, have made it possible to narrow the choice for the exploratory phase of the geothermal development project to the Hanlé zone. This exploratory phase will involve the drilling of four boreholes to a depth of 1,500 to 2,000 meters. If any of these wells is successful (in terms of commercial viability), the development phase could follow.

The drilling of the first well began in January 1987. The second well followed shortly after.

The potential of a geothermal resource depends on the volume of the subterranean reservoir (representing the total exploitable energy), the rate of flow of the geothermal fluid, and its temperature. These parameters determine the electrical power which can be obtained from each production well.

Although the total fluid flow may be increased by increasing the number of wells, the temperature of the fluid represents a fixed characteristic of the resource which significantly influences the economics of the project.

To show the importance of fluid temperature in the economics of geothermal power, annex 3.2 presents an analysis of the electrical energy obtained from fluids of temperatures ranging from 220 °C to 300 °C. The electrical power produced depends partly on the quantity of steam produced by the flashing of the geothermal fluid at the wellhead, and partly on the difference in pressure between the steam pressure at the turbine's intake and the low pressure in the condenser.

An optimal separator pressure exists for each fluid temperature. Table A 3.2.4 shows the influence of the temperature of the geothermal fluid on power production. For example, a temperature of 240 °C makes possible an increase in electrical power of the order of 25 % compared with a fluid at 220 °C. At 260 °C one obtains a power increase of 55 %.

It follows that it is of the utmost importance to identify and exploit the geothermal fields with the highest temperatures. Provided that the criteria of permeability and of fluid composition are met, these fields will produce the cheapest electrical energy.

The development and implementation of a national program to assess the country's geothermal potential is a long-term project that requires technical expertise, perseverance, and a willingness to take risks.

However, if successful, the exploitation of geothermal energy in Djibouti will have a major positive impact on the social and economic development of the country.

Figure 3.4.1. shows the main areas of geothermal potential in Djibouti /3.6/.

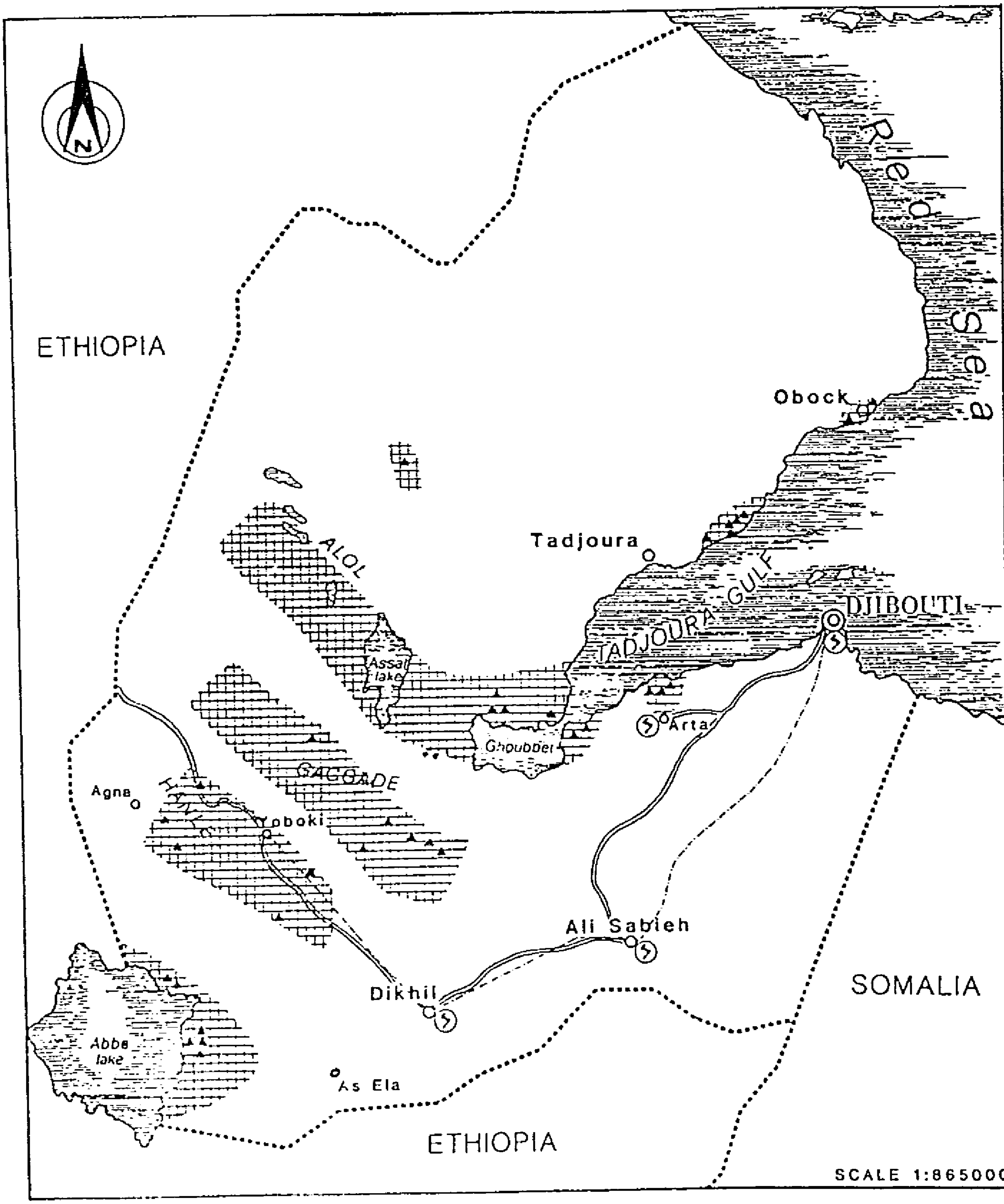

Figure 3.4.1. Principal Geothermal Zones in Djibouti

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ANNEX 3.1 COST OF ELECTRICAL POWER GENERATED BY WIND TURBINES AND PHOTOVOLTAIC SYSTEMS

For the wind turbines the computation is based on an analysis of two commercial systems, the Whirlwind A 120 wind turbine and the US Windpower model 56-50. The technical details are presented below.

Table A 3.1.1. Wind Turbine Characteristics

	WHIRLWIND A 120	US WINDPOWER 56-50
Rated power, kW	2	50
Rated windspeed, m/s	11.2	9.8
Start up windspeed, m/s	3.1	3.6
Cut out windspeed, m/s	13.4	17.9
Rotor diameter, m	3.05	17.07
Number of blades	2	3

The estimate of the electrical energy produced each year is based on two assumptions:

- the wind speed frequency follows a Rayleigh distribution

- the power output of the wind turbines follows a quadratic curve between the start-up wind speed and the rated windspeed. The power output then remains constant at the rated power up to the cut out windspeed when it drops to zero. This approach is discussed in more detail in monograph /3.7/.

The power produced by the two generators can then be estimated as shown in Table A 3.1.2 overleaf.

Table A 3.1.2. Wind Turbine Power Production, kWhe/year

Wind turbin	mean windspeed, m/s 3	4	5	6	7	8
Whirlwind A 120	712	1818	3234	4583	5549	6057
U.S Windpower 56-50	18508	53092	98283	144401	184381	214371

The cost of electricity is computed on the basis of the installed cost of the wind turbines, taken here as $2,000 per rated kW. The capital cost is amortized over a period of 10 years at an interest rate of 10 percent. Installation and maintenance costs are estimated at $0.01 per kilowatt hour. The results of this analysis are shown in Table A 3.1.3 below.

Table A.3.1.3 Cost of Power Generation from Wind Turbines

	mean windspeed, m/s 3	4	5	6	7	8
Whirlwind A 120						
capital cost, $	4000	4000	4000	4000	4000	4000
cost of capital, $/yr	651	651	651	651	651	651
operation and maintenance:						
$ 0.01/kWhe $/yr	7	18	32	46	55	61
total cost, $/yr	658	669	683	697	706	712
electricity production						
kWhe/yr	712	1818	3234	4583	5549	6059
cost of electricity,						
US cents/kWhe	92	37	21	15	13	12
US windpower 56-50						
capital cost, $	100000	100000	100000	100000	100000	100000
cost of capital, $/yr	16275	16275	16275	16275	16275	16275
operation and maintenance						
$ 0.01/kWhe $/yr	19	531	983	1444	1844	2144
total cost, $/yr	16294	16806	17258	17719	18119	18419
electricity production						
kWhe/yr	18508	53092	98283	144401	184381	214371
cost of electricity						
cents/kWhe	88	32	18	12	10	9

The figures presented in the table above can be compared with the cost of electricity produced by a photovoltaic system. It is assumed that solar panels can be installed for $10 per peak watt (Wp), and that 1 Wp will produce an average of 5 Wh/day of electricity, given the high levels of insolation in Djibouti.

A capital recovery factor of 0.13147 (15 years at 10%) is employed. The cost of operation and maintenance is taken as $0.01 per kilowatt hour, identical to that used for the wind turbines. Based on these assumumptions, the cost of photovoltaic power is given by:

$$\frac{10 \times 0.13147 + 0.01\ (5 \times 365/1000)}{5 \times 365/1000}$$

$$= \$0.73 \text{ per kilowatt hour}$$

It would therefore appear that wind electric systems are more economic than photovoltaic systems, provided one can rely on average windspeeds greater than about 3.5 m/s. Many areas in Djibouti have average windspeeds that are greater than this value, (see table 3.3.1.).

It may be noted that if the cost of solar panels drops to $2.00 per watt peak, which could occur before the end of the decade, the cost of photovoltaic electricity will be about 15 cents per kilowatt hour, and photovoltaic systems will be more economic than wind electric systems except in regions where average windspeeds are equal to or greater than 6 m/s. Mean windspeeds at this level have never been recorded in Djibouti, although they might possibly be found in certain coastal areas, or in the mountains in the north.

ANNEX 3.2 POWER PRODUCTION FROM GEOTHERMAL FLUIDS AT DIFFERENT TEMPERATURES

Geothermal fluid from a production well is flashed at the wellhead into steam and the more concentrated brine by dropping the pressure of the fluid in a separator. The steam is then expanded through a turbine to produce electricity.

The design pressure of the separator, and the quantity of steam thus produced, is a function of the temperature of the geothermal fluid and of other thermodynamic factors. For different fluid temperatures, there exists an optimal separator pressure that will produce a maximum amount of electrical power.

The fraction of steam produced from geothermal fluids at different temperatures and separator pressures is shown in Table A 3.2.1.

Table A 3.2.1. Fraction of Steam Produced for Fluids of Different Temperatures

	Separator Pressure (bar)		
Fluid temperature	3	5	7
220°C	0.177	0.145	0.120
240	0.220	0.190	0.165
260	0.265	0.235	0.215
280	0.312	0.285	0.265
300	0.362	0.335	0.315

However, although lower separator pressures produce greater quantities of steam, the enthalpy of the steam produced is lower. An optimal combination of steam fraction and adiabatic drop will produce the greatest amount of electric power.

The steam from the separator is expanded through a turbine, and is then condensed in a condenser operating at below atmospheric pressure (typically 0.1 bar). At this pressure the saturation temperature of steam is 45 °C, provided that the temperature of the cooling circuit is no higher than 35 °C.

The expansion of the steam passing through the turbine, and the transfer of energy from the steam to turbine, can be represented on a Mollier diagram as indicated in Figure A 3.2.1.

The vertical lines represent the ideal isentropic path of the steam as it expands in the turbine. The steam pressure drops from that of the separator (3, 5, or 7 bar), to the pressure in the condenser (0.1 bar). The energy that is transferred to the generator is equal to the isentropic enthalpy drop reduced by a factor that accounts for the conversion efficiency of the generator--assumed here to be 76 percent.

Based on the values given in the Mollier diagram, the output of the generator can be estimated in kilojoules of electricity (kJe) per kilogram of steam. These values are shown in table A 3.2.2.

Table A 3.2.2. Electrical Energy Produced at Different Separator Pressures per Unit Mass of Steam

Separator pressure bar	Enthalpy of saturated steam at separator pressure, kJ/kg	Enthalpy of saturated steam at condenser pressure, kJ/kg	Electrical energy produced kJe/kg
3	2725	2583	108
5	2749	2583	126
7	2764	2583	138

The optimum pressure in the separator for a given fluid temperature is found by combining Tables A 3.2.1. and A 3.2.2., and by calculating the amount of electrical energy produced by a kilogram of geothermal fluid.

At each fluid temperature, the steam fraction given in Table A 3.2.1 is multiplied by the electrical energy coefficient appearing in the last column of Table A 3.2.2. The results of this calculation are shown in Table A 3.2.3.

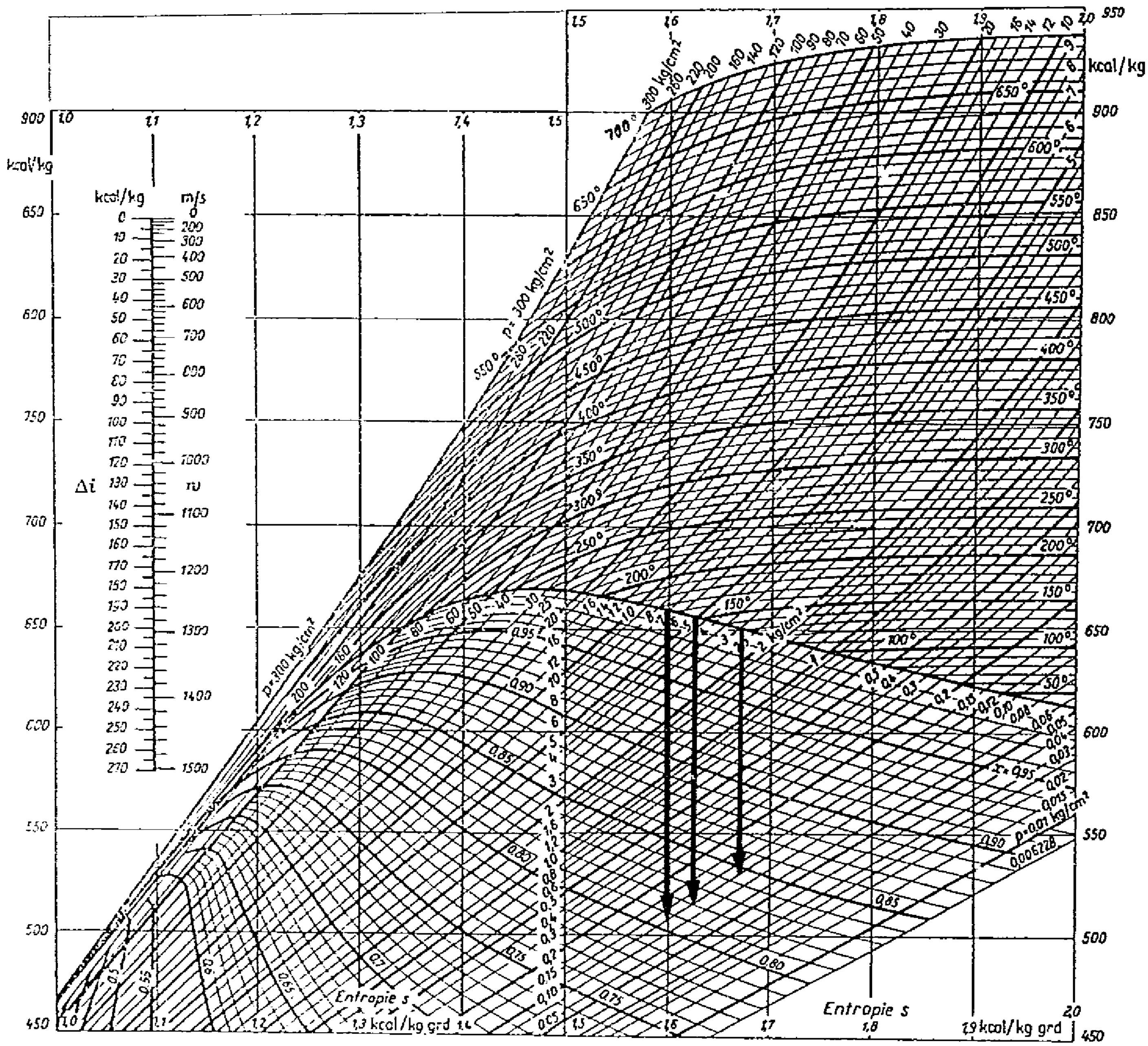


Figure A3.2.1. Mollier Diagram for Water

Table A 3.2.3 Electrical Energy Produced from Geothermal Fluids at Different Temperatures, kJe/kg fluid

Fluid temperature °C	Separator pressure, bar 3	5	7
220	19.1	18.3	16.4
240	23.8	23.9	22.6
260	28.6	29.6	29.5
280	33.7	35.9	36.3
300	39.1	42.2	43.2

The optimal separator pressures are those that produce the most electricity per unit of geothermal fluid. From the data shown in Table A 3.2.3. the optimal separator pressure can be determined. These values are shown in Table A 3.2.4.

Table A 3.2.4. Optimal Separator Pressures and Increase in Electrical Output at Different Fluid Temperatures

Fluid temperature °C	Optimal separator pressure bar	Electrical energy produced kJe/kg fluid	Percentage increase in output
220	3	19.1	-
240	5	23.9	+ 25.1
260	5	29.6	+ 55.1
280	7	36.3	+ 90.0
300	7	43.3	+ 126.2

It is clear that the electrical energy output is extremely sensitive to the temperature of the geothermal fluid. A modest temperature increase from 220 °C to 240 °C produces a 25 % increase in power production.

If fluids with temperatures greater than 280 °C could be found and exploited, the amount of power produced would be about twice that produced by geothermal fluids at 220 °C.

CHAPTER 4

SECONDARY ENERGY

4.1 CHARCOAL

4.1.1 National Production

In Djibouti, the majority of charcoal comes from :

- the district of Tadjourah, particularly from the areas on the coast between Tadjourah and Sagallou (e.g.Kalaf), but also from the wadis between Tadjourah and Randa, as well as the area around Obock in the District of Obock.

- the district of Dikhil, predominantly in the area of As-Eyla and Garabous.

Smaller quantities are produced on the plain of Djibouti south-west of Loyada; one also finds occasional production in and around the town of Djibouti /4.1/.

The wood used for making charcoal is often too cumbersome to transport and to be used as fuelwood because of its size or length. This wood consists of dead trunks or large branches which have been uprooted by the wind or by the flooding of the wadis. For this reason, and since one can find sand in these areas, a large quantity of charcoal is produced in the wadis.

An open fire is the most frequently used method of production. The charcoal-maker makes a pile of wood, sets fire to it and then covers it with sand. The wood is gradually transformed into charcoal. This method is certainly the most simple, but the worst from the point of view of energy efficiency.

The production of charcoal is very low during the summer for a number of reasons :

- There is a significant drop in demand.
- The Khamsin is a real danger, given the method of production.
- The wood made available by the flooding of the wadis has been used up.
- The hot weather.
- Many charcoal-makers are also nomadic farmers (this is the case of the charcoal-makers on the coast between Tadjourah and Sagallou).

It is difficult to estimate the quantities produced annually by the charcoal-makers; quite often they are unable to estimate the amounts themselves. Moreover, many of them only make charcoal from time to time.

The majority of charcoal-makers are farmers, nomadic or settled, for whom the production of coal is a secondary activity.

In general, they work for themselves. However, in As-Eyla, in one unusual case, the charcoal-makers are wage-earners for six months of the year, employed by a person who stocks the charcoal and who organizes the marketing. This is also one of the few groups which uses a relatively efficient method of production. In this case, the employer pays two charcoal-makers.

It is extremely difficult to estimate the exact number of charcoal-makers as it is not easy to locate them all and many of them work only part-time.

According to the deputy of Tadjourah there are between fifteen and twenty charcoal-makers in the District. The Commissioner of Obock counted eight workers. In As-Eyla one can count five or six, with another three or four in Garabous.

From Djibouti-ville, the sacks of charcoal are carried to the District centres in the same way that wood is often transported, i.e. carried along the tracks by camels. Charcoal coming from Tadjourah and Obock also follows the same route as that of wood.

As noted in Chapter 1 the total consumption of charcoal is estimated at 842 TPE, of which about 50 TPE are imported from Somalia.

On the wholesale market one finds different sizes of sacks being sold:

- large sacks (between 38 and 50 kg)
- average sacks (20 to 27 kg) and
- small sacks (7 to 8 kg).

The supply routes for both wood and charcoal are shown schematically in Figure 4.1.1.

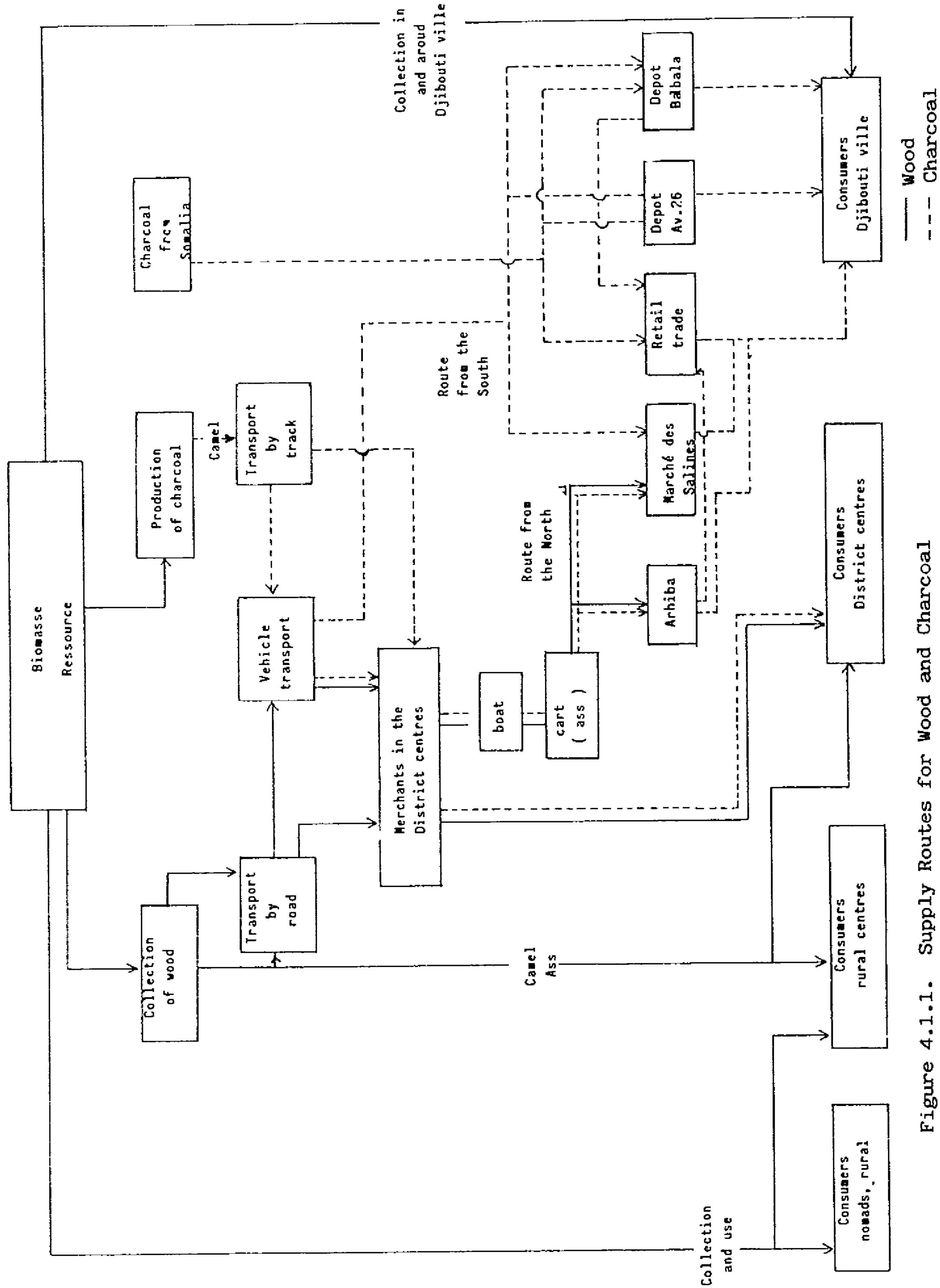


Figure 4.1.1. Supply Routes for Wood and Charcoal

4.1.2. Importation of Charcoal

A certain amount of charcoal comes from Somalia. Very little data exists on the amounts imported as no controls are in place. During the hot season only very small quantities of charcoal are imported.

4.1.3. Economic Aspects

The retailer gets his supplies from the wholesale markets, or sometimes directly. The charcoal is sold in packets or small bags, sometimes by weight.

The price per kg varies enormously: between 66 FD and 153 FD per kg. The variations seem illogical as it is often more advantageous to buy several packets costing 20 FD rather than a small bag costing 100 to 200 FD.

Table 4.1.2. Retail Cost of Charcoal in Djibouti

Denomination	weight, g	price in FD	price per kg FD
20 FD	235	20	85
Average packet	291-300	20	68-66
" "	291	30	104
small bag	355	50	140
1/2 kg	655	100	152
200 FD bag	1835	200	109
little bag	1300	200	153

According to the DINAS survey, the average household spends 97 FD for 1 kg of charcoal.

Taking the country as a whole, the fuelwood and charcoal supply system, although apparently economically unimportant, should be recognized as a real economic activity which contributes to the monetary income of a number of social groups: wood-cutters and nomads for instance.

4.2. IMPORTED OIL PRODUCTS

4.2.1. Sources of Supply

Imported oil products account for the major part of the energy consumed in Djibouti. The possibility of finding petroleum resources in Djibouti is considered to be highly unlikely because of the unfavorable geology of the country.

Three oil companies : Mobil Oil, Shell, and Total share the market. Mobil Oil holds 50 % of the market, the other two companies hold 25 % each.

The system of supply is well matched to the demand in the sense that, up to the present time, there has been no shortage of the products on the market.

The oil companies are based in the Port of Djibouti, a strategic point which facilitates their operations and helps reduce their costs. Each company has its own petrol stations located both in Djibouti ville and in the Districts.

Large consumers such as EdD and the French Army solicit bids from all the companies in the hope of obtaining reduced prices and more favorable terms of supply. For example, the lack of fuel storage tanks at EdD means that almost daily supplies of fuel are required.

4.2.2. The Role of the Public Hydrocarbons Establishment

The Public Hydrocarbon Establishment (EPH) was established by Presidential order on July 14th, 1980. The importation of hydrocarbons and its effect upon the balance of the economy and Gross Domestic Product (GDP) is only one of the reasons for the setting up of this organization.

For the Government, it is a necessary instrument for promoting economic and social policies consistent with the economic development of the country.

The activities of this establishment can be summarized as follows:

- EPH is responsible for supplying the national demand for hydrocarbons at the most advantageous price, and in the most effective manner.

- the agency deals in only 4 types of fuels: super gasoline, ordinary gasoline, Diesel fuel (gas-oil), and kerosene.

- the agency regulates prices with the aim of stabilizing the market.

Since EPH sets prices for the four fuels mentioned above, it is able to maintain the price of the different products at higher or lower levels. The prices of Diesel fuel and kerosene, for example, are kept at a low level for economic and social reasons by means of subsidies.

A comparison of the recent fluctuations in international oil prices, and the stable prices found in Djibouti, clearly shows the ability of Goverment policy to regulate prices and to stabilize the market.

4.2.3 Impact on the Economy

According to figures published by DINAS in 1983, the cost of petroleum imports was of the order of 6 billion FD--about 10 % of the GDP, and 32 % of total imports.

Although the cost of imported petroleum entails a significant disbursement of foreign exchange, the sale of petroleum products in Djibouti generates a substantial revenue for the Government.

The financial management of the importation and sale of petroleum products is one of the most important responsibilities of EPH, and one which has obvious implications regarding the overall consumption of energy in Djibouti.

4.3. ELECTRICITY

4.3.1. General Overview

The electrical supply system in the Republic of Djibouti is only really developed in the main urban centres where the transmission and distribution system is managed by EdD /4.2/.

The production of electricity relies exclusively on Diesel generators fuelled by imported oil products. The total electrical production by the EdD power stations in 1985 was 164.2 GWh, or 382 kWh per capita.

The amount of electricity produced by other power plants owned by various organizations, or by private owners, is not precisely known.

However, it is estimated that this supplementary production does not amount to more than 5 % of EdD's production. The total production of electricity per capita in 1985 was therefore about 400 kWh per capita.

At the present time, the transmission of electricity is not very well developed. Only two transmission lines exist in the country: one 20 kV line 86 km long, and a 60 kV line 6 km long.

4.3.2. Analysis of Electricity Demand

4.3.2.1. Evolution of Electricity Consumption

In the discussion which follows, we refer only to electricity produced and distributed by EdD. One should note, however, that this represents around 95 % of the total amount of electricity produced in the country.

The statistical data concerning the evolution in the production of electricity are shown in table A 4.2.1 of annex 4.2.

It can be seen that in 1985 Djibouti's network represented 96.7 % of total production, the remainder being divided between the four other generating stations which include those at Ali Sabieh and Dikhil which were interconnected in 1985.

The production of electricity in 1985 was as follows :

	GWh	%
Djibouti-Arta network	158.827	96.7
Ali Sabieh	0.911	0.6
Dikhil	1.190	0.7
Obock	0.640	0.4
Tadjourah	2.677	1.6
	164.245	100 %

The annual rate of increase in the production of electricity during the past seven years is 7.1 % overall, but there are marked differences among the various District centres as shown in Table A 4.2.1.

Taking the centres together, the average rate of increase in production was 12.3 % -- significantly higher than that of the main network which was 6.9 %.

The difference in the rates of growth has progressively reduced the part of the total EdD production provided by the Djibouti-Arta network; the contribution has fallen from 97.4 % in 1980 to 96.7 % in 1985.

Table A 4.2.2 of annex 4.2 shows the evolution in the production of electricity, energy output and peak demand of the main network between 1971 and 1985. Also shown is the consumption of electricity by auxiliary plant services, and the duration of the peak demand.

Total electricity consumption is about evenly divided between two consumer groups: small consumers who receive a low voltage supply, and the rest which includes the average and large consumers. The latter group, which subscribe to a power supply of over 36 kW, are supplied with mid-range or low voltage power.

Table A 4.2.3. shows that a balance has been maintained between these two groups as far as the network in Djibouti is concerned with no great long term variation over the period 1971-1985. There are certain variations from year to year, due mostly to random factors such as delays or anomalies in billing.

The last column of Table A 4.2.3. also shows changes in transmission losses during the same period, which vary on average between 10.5 and 12.9 %. This aspect will be commented on in more detail later. Figure 4.3.1. shows the evolution in electrical energy production and peak demand in the main network since 1971.

4.3.2.2. Seasonal and Daily Variations in Electricity Demand

Electricity consumption in Djibouti is characterized by strong seasonal fluctuations. Table A 4.2.4 shows electricity production and peak demand for each month in 1985. It can be seen that the ratio between the maximum value, which occurs during the hot season and the minimum value, is 2.59 for energy and 2.20 for peak power.

Figure 4.3.2 (a) shows the peak demand profiles for each month during the past three years. The marked seasonal variations are very apparent, and seem to be increasing.

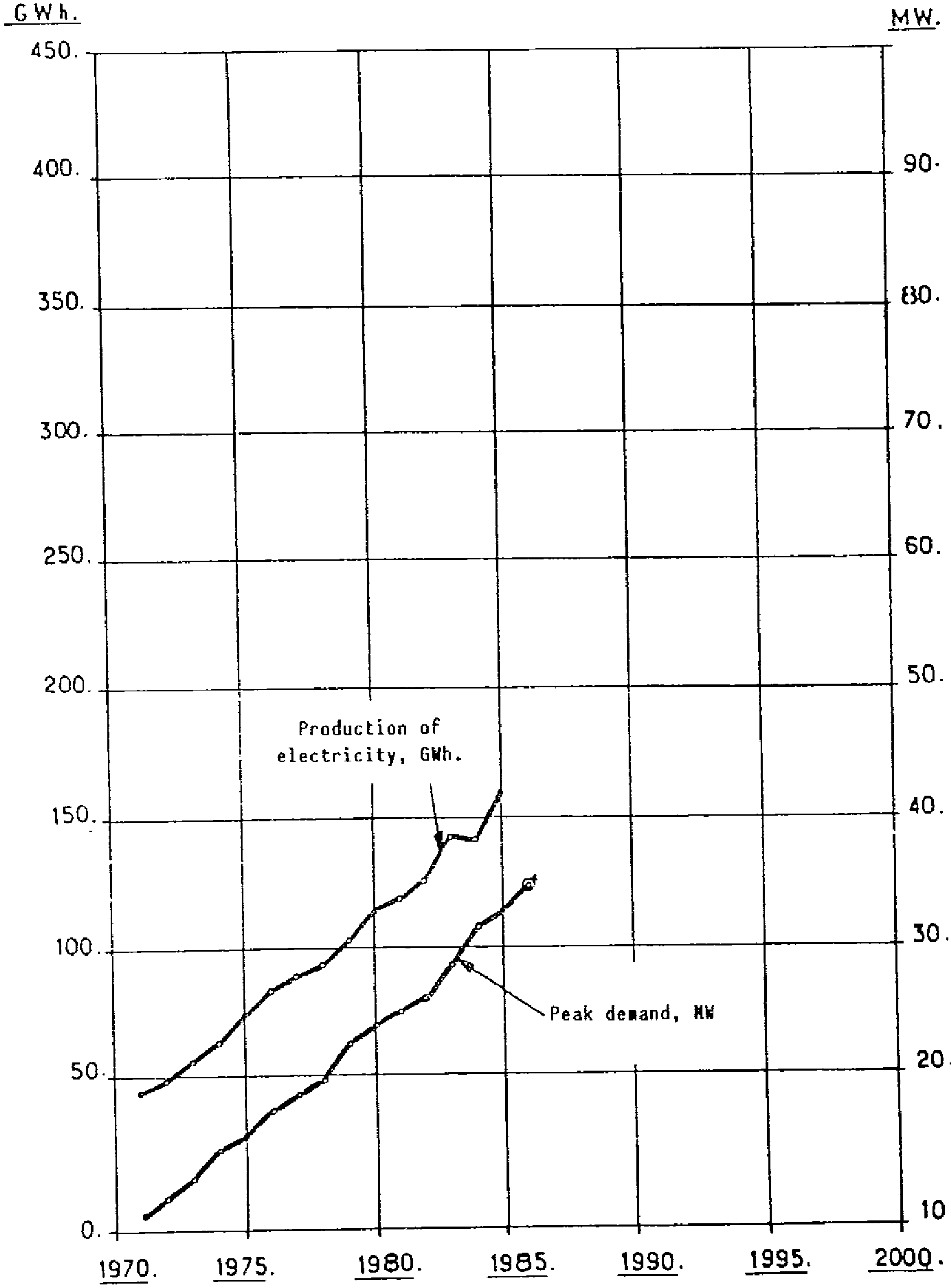
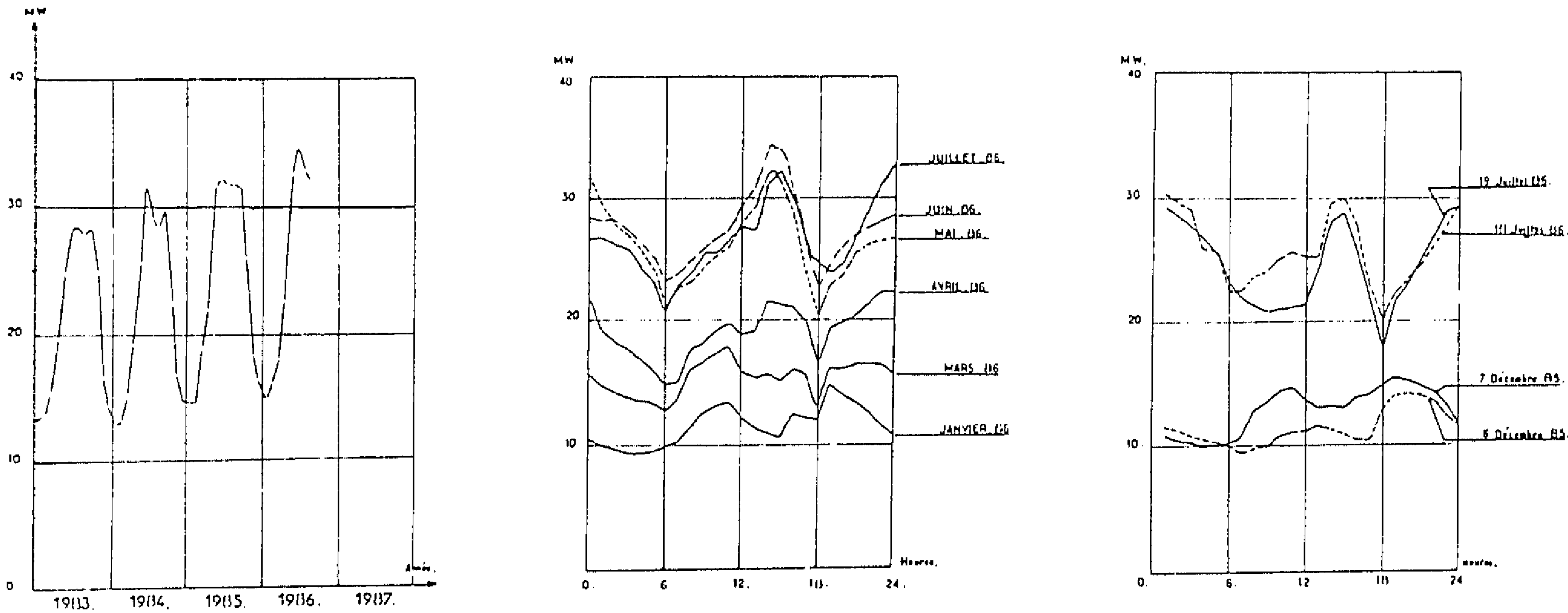


Figure 4.3.1. Increase in the Production of Electricity and in Peak Electrical Demand



(a) (b) (c)

Figure 4.3.2. (a) Seasonal variations in electrical demand - peak demand
(b) Seasonal variations in daily electrical demand
(c) Weekly variations in daily electrical demand

——— Work day

----. Friday (non work day)

These curves clearly show the considerable impact which the use of air-conditioning and refrigeration has on the total electricity consumption in Djibouti.

Figure 4.3.2 (b) shows the daily fluctuations in demand over several typical months of the last year. One can clearly see that these fluctuations are quite different from one season to another. During the cool season, the demand curve has two peaks -- a characteristic of the moderate climate. One peak is in the evening, at sunset, and the other is in the morning at the start of the work day. However, during the hot season, the peaks occur during the night around 11 or 12 p.m., and during the siesta time around 2 to 3 p.m. During the summer, work hours correspond with the low points in the demand curve.

These variations in the curves show that it is household air-conditioners which have the most significant impact on peak electrical demand.

Weekly variations in demand are shown in Figure 4.3.2 (c). One can once again observe that domestic consumption is significantly higher than commercial consumption during the hot season.

An analysis of the production curves of EdD shows that the weekly peak generally occurs on Wednesday and that Friday is frequently the day with the least consumption.

These observations, however, are always a function of climate since variations in temperature, relative humidity, and the wind have a significant impact on the use of air-conditioning.

It should also be noted that during the period of Ramadan there is a marked increase in the use of air-conditioning.

4.3.2.3. Demand Curves for Different Categories of Consumers

In order to analyze the structure of electricity consumption disaggregated by class of consumer, it is possible to record the level and variation in consumption at certain points in the distribution system.

This technique was applied by EdD during October 1986, but the results obtained should be viewed with caution for the following reasons:

1) The samples, although carefully chosen, cannot assure complete homogeneity. The consumption of one large consumer can significantly influence the demand curves.

For example, if one takes the consumers subscribing to 1 kVA, with two fans and two lights, the demand would be only about 200 W. However, a single consumer with an air conditioner would have a demand of 2 kW -- the equivalent of ten 1 kVA consumers. This demand clearly has a marked impact on the recorded levels of consumption.

This example points out the risks involved in analysing electrical demand based on the data presented in Figures 4.3.3 (a) and 4.3.3 (e)

2) The data was collected for 2 days during October--a month falling between the period of heavy electricity consumption during the hot months, and the period of modest consumption during the cooler months of the year. It would therefore be useful to repeat the analysis, this time taking data in the summer and in the winter, in order to assess the influence of temperature and humidity on the demand.

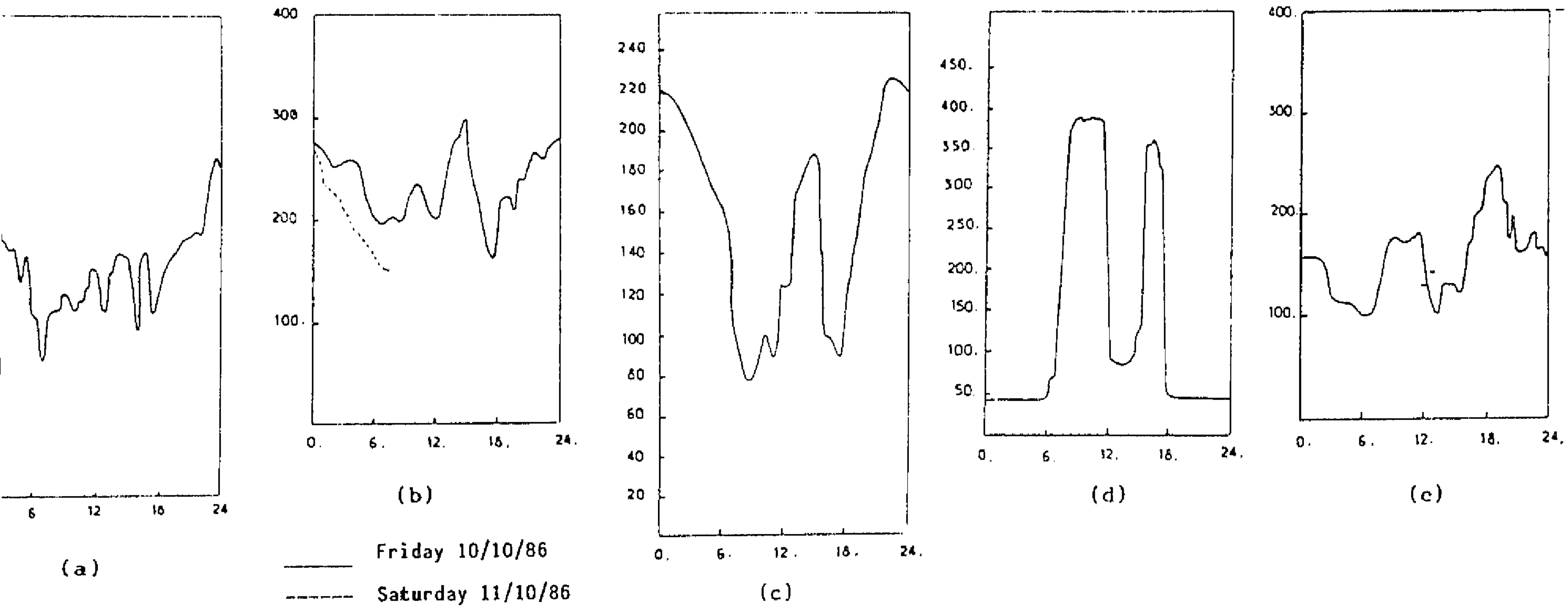
These data, supported by more detailed studies, would provide a data base which would permit marginal costs to be much more precisely calculated.

However, there is another technique which can be used to analyse the structure of the demand for electricity. Surveys of the different consumer groups can be carried out in order to determine the pattern of electricity use, the appliances and equipment in operation, the hours of use, etc. This information is then cross-checked against the actual electricity bills.

This approach has been taken by ISERST, and has permitted the definition of the demand curves for various categories of consumers during the different seasons. These curves are shown schematically in Figures 4.3.3 (f) and 4.3.3 (g).

These curves, which require further study, are interesting in a number of ways because the curves allow one to study the creation of the daily peaks in the demand curves.

Refrigeration is responsible for the base of the demand, which varies appreciably with the ambient temperature. In the middle of the day, the siesta is accompanied by an electrical consumption by fans or air conditioners according to the type of household. Finally, at around 6.30 pm, lights are turned on, perhaps with a television, followed by fans and air conditioners. These appliances produce the second daily peak.



igure 4.3.3 Demand curves for different categories of consumers

a) Residential (modest); measured 5–6 October 1986 ; post : Quartier 4 (P = 800 KVA)
b) Residential (average) ; measured 9–11 October ; post : ISSA (P = 630 KVA)
c) Residential (upper) ; measured 6 October ; post : BERRY (P = 630 KVA)
d) Offices ; measured 7–8 October 1986 ; post : CITE MINISTERIELLE (P = 630 KVA)
e) Commercial ; mcasured 11–12 October 1986 ; post : LONDRES (P = 630 KVA ,

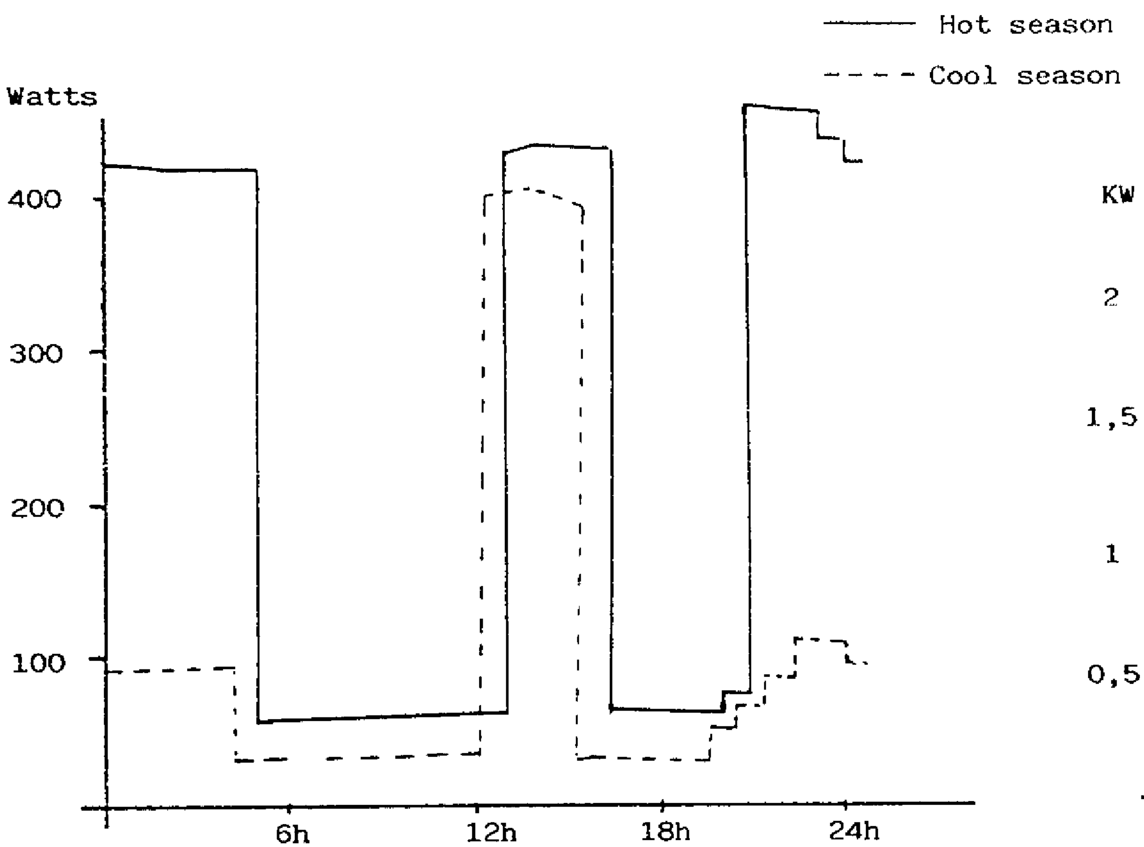


Figure 4.3.3.f Daily Variation in Electricity Consumption (from statistical survey) - 1 KVA subscribers

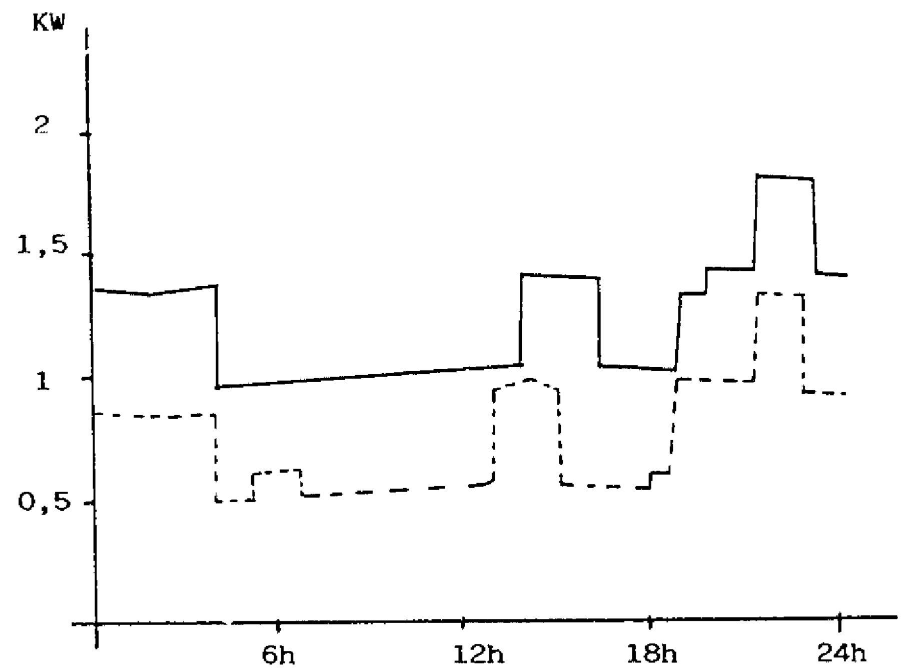


Figure 4.3.3.g Daily Variation in Electricity Consumption (from statistical survey) - 6 KVA subscribers

A comparison of the two techniques, the first based on measuring the consumption of consumers as a group, the second based on a survey of individual consumers, allows one to cross-check the profile of the demand curves, and also points out the dangers of basing a study of tariffication solely on measuring the consumption of a group of consumers whose homogeneity is open to question. The air conditioning load is disproportinately heavy, and a clear distinction should be made between households that employ such appliances and those that do not.

In effect, as Figures 4.3.3 (f) and (g) clearly show, the demand peaks during the hot period are due to air-conditioning. This contribution should be taken into account when calculating the marginal cost of production, and the appropriate tariffs to be applied.

As for offices and commercial activity, Figures 4.3.3 (d) and (f) show that consumption generally takes place at those times when domestic consumption is lowest.

It can be concluded that the peaks in the aggregate demand curve are almost exclusively due to domestic consumption.

The business and commercial sectors consume electricity mainly during the low periods in domestic consumption. This combination produces a daily demand curve which is relatively flat -- a load factor of around 0.8 during hot months, 0.85 during the mid-season months, and about 0.76 in the cool season.

4.3.2.4. <u>The Structure of Electricity Consumption</u>

Annex 4.2 presents a detailed analysis of electricity consumption. Tables A 4.2.5 (a) and (b) show consumption in the low voltage range, and Table A 4.2.6 shows consumption in the mid-range voltage. A statistical analysis of the consumption by the different subscribers can be seen in Figures A 4.2.1 (a) and (b).

For the low voltage consumption it can be seen that :

- 90 % of low voltage subscribers are domestic customers; they account for 87.1 % of the total consumption of low voltage electricity.

- Among these domestic consumers, 65 % subscribe to a power level of 1 kW and benefit from this favorable tariff.

- The average monthly consumption in the summer of 206 kWh by subscribers using 1 kW is reached by only 35 % of the group. The most frequent level of consumption by these subscribers is between 30 and 180 kWh per month.

Table A 4.3.6 shows the consumption in the mid-range voltage for each branch of activity for 1986.

It should also be noted that a single subscriber may include several households. For instance, there are 21,305 households with electricity, but only 14,711 domestic subscribers in the 1-36 kW range.

4.3.2.5. Reactive Energy

The consumption of reactive energy in the main Djibouti-Arta network is quite moderate. The power factor of production is generally between 0.85 and 0.9, which can be considered satisfactory. However, although generally valid, this conclusion should not lessen efforts to improve the power factor where this appears to be necessary. In fact, the overall power factor is favorable mainly because of the predominance of domestic consumption and the use of air conditioners--equipment which is well compensated.

This characteristic produces seasonal fluctuations in the power factor as shown in Figure 4.3.4. In the zones of the distribution network dominated by industrial consumption such as the port, the control of reactive power consumption is still necessary, and the electricity tariff structure should provide the appropriate incentives for these large consumers.

Figure 4.3.4 and Table A 4.2.7 of annex 4.2 show data pertinent to the discussion above.

4.3.3. Analysis of the Supply and Distribution of Electricity

4.3.3.1. Power Stations

Installed Capacity

At the present time, EdD operates six power stations of which two are located in Djibouti ville and four are located in the District centres. For the most part, two types of units are installed at these plants: Diesel generators with a rated power output of between 2 and 15 MW running on fuel oil, and Diesel generators of between 100 to 600 kW running on Diesel fuel.

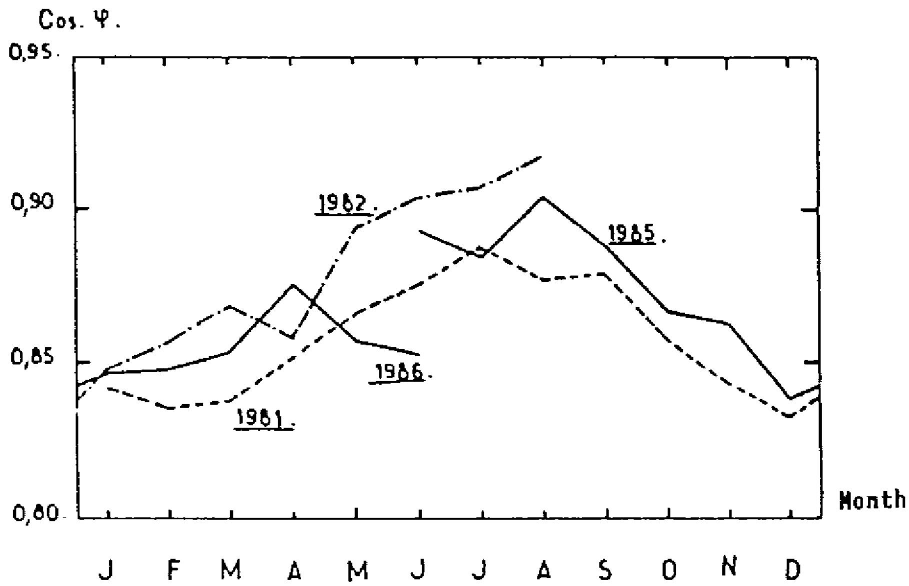


Figure 4.3.4 Changes in Average Monthly Power Factor,

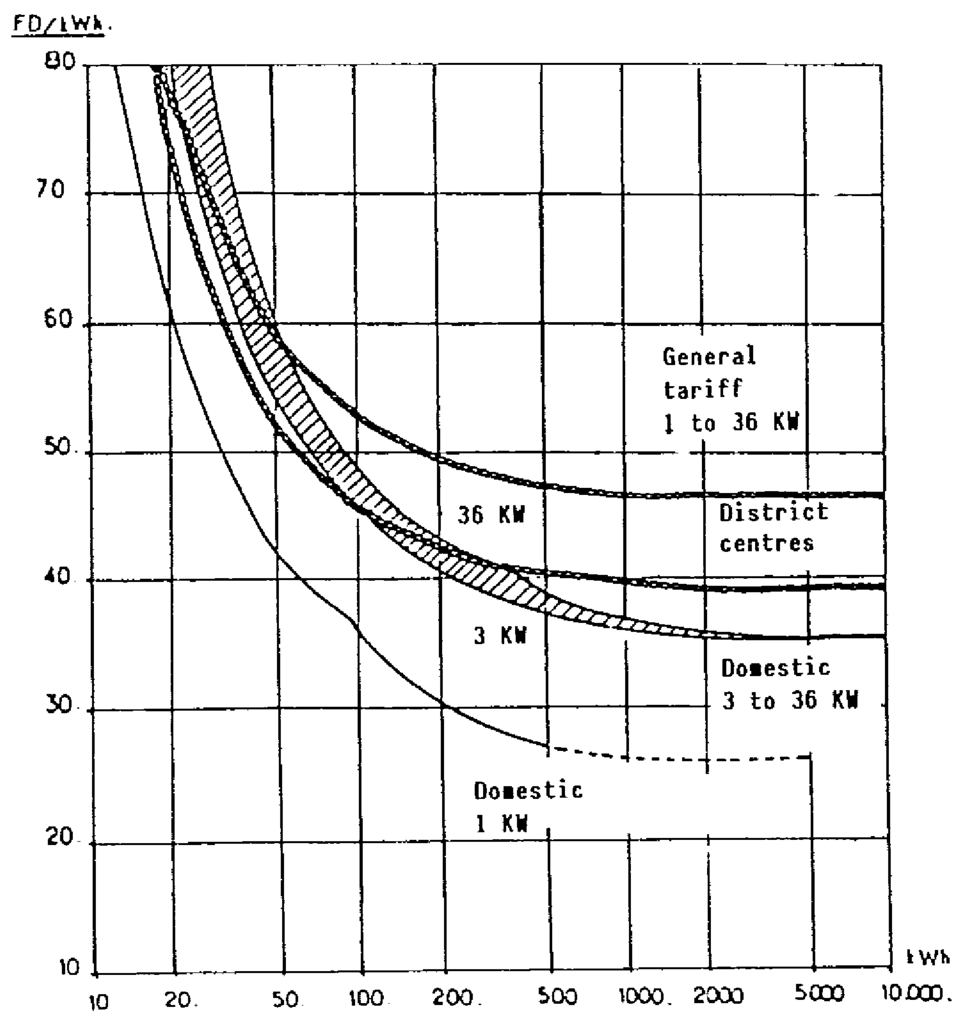


Figure 4.3.5 Present Tariffs - Low Voltage

The larger units burning fuel oil are installed in Djibouti ville, while the smaller generators run in the District centres as shown in the table which follows.

	number of units	total power installed MW
Generators in Djibouti ville	12	74.5
Generators in the District centres	15	3.8
	27	78.3

A list of these units is given in Tables 4.3.1. and 4.3.2. It should be noted that many of these units are older than the normal 15 year life time, but are maintained in working condition in reserve.

With respect to electricity produced by operators other than EdD, the data are incomplete, but their contribution is of only minor consequence for energy planning purposes.

Until 1984, there were often interruptions in the supply of electricity in Djibouti. This was partly due to delays in installing new generators. In 1985, after the installation of two 15 MW generators, the situation changed completely, and there is now an excess capacity.

If one calculates the gross capacity coefficient -- the ratio of the installed capacity to the peak demand -- for each distribution network, one obtains the figures shown in the table which follows.

The coefficient of 2.16 for the Djibouti-Arta network, which is quite high, is a result of the choice of 15 MW as the unit power of the new generators installed in 1985.

	Installed capacity MW	Peak demand MW	1986 gross capacity coefficient
Djibouti network	74.5	34.5	2.16
Dikhil-Ali Sabieh	2.16	0.48	4.50
Tadjourah	1.28	0.60	2.13
Obock	0.32	0.17	1.88
	78.26	35.75 *	2.19

* sum of non-coincident peaks

Table 4.3.1 Power Station Capacity (Djibouti ville) as of 31 December 1985

Station and unit	Commencement of service	Hours of operation, 31.12.85	Installed power kW	Operating power kW
MARABOUT				
G1	1963	42858	2000	1500
G2	1963	42653	2000	1500
			4000	3000
BOULAOS 1				
G1	1976	54957	6000	5000
G2	1979	57548	4500	3800
G3	1969	74101	4500	3800
G4	1967	73783	4500	3800
G5	1965	71959	4500	3800
G6	1974	55255	4500	3800
G7	1980	24493	6000	5000
G8	1982	19744	6000	5000
			40500	34000
BOULAOS 2				
G21	1985	5212	15000	13700
G22	1985	4535	15000	13700
			30000	27400
TOTAL			74500	64400

Table 4.3.2. EdD Power Station Units in the District Centres

	Operating power kW
Ali Sabieh : 1 x 100 + 1 x 200 kVA	240
Dikhil : 2 x 200 + 2 x 400 + 2 x 600 kVA	1920
Obock : 3 x 135 kVA	324
Tadjourah : 4 x 400 kVA	1280
	3764

This increment of installed power (15MW), equal to 43 % of the network's peak demand, is unusually high for a relatively mature power system where ten generators are already in operation. However, this increment in capacity was introduced after technical and economic studies pointed out the advantages of operating, and successively installing, a series of generators with the same unit power.

At Tadjourah, 3 generators are installed; the coefficient of 2.13 is within normal limits. At Obock, which also has 3 generators installed, the coefficient of 1.88 shows that the system is approaching saturation, and that additional capacity will soon be necessary. As for the Dikhil-Ali Sabieh network, the very high coefficient of 4.50 is the result of a new power station which started up in 1985. This new station will permit the retiring of some of the older generators (and possibly re-installing them in other Districts). On the whole, the relatively high overall coefficient of 2.19 suggested a slight over-capacity, but not one which is extreme.

Specific Fuel Consumption

The specific fuel consumption by the power stations in Djibouti changed noticeably in 1985 after the installation of the two new generators. Previously, the average consumption of fuel was about 250 g/kWh. In 1985, however, consumption dropped to 231 g/kWh, and in the first eight months of 1986 it fell to 226 g/kWh. This reduction is due to the two new generators whose average specific rate of fuel consumption is around 220 g/kWh. Nevertheless, this latter figure remains disappointing since the fuel consumption of the new generators was expected to be around 200 g/kWh. With the generators now in service, the specific fuel consumption for the Djibouti network should average around 225 g/kWh.

During the last few years, the actual consumption rate of the generators in the District centres was about 300 g/kWh (see table A 4.2.8. of annex 4.2). But the figures vary considerably depending on the condition of the generators. The equipment in Tadjourah, and especially the new plant in Dikhil, have efficient generators which one would expect to consume about 260 g/kWh or even less.

This specific fuel consumption should be reached in the next few years as the more inefficient and the smaller generators are retired or held in reserve. This figure will be considered as an average for the District centres.

The consumption of lubricants has been very high over the past years -- greater than 4 g/kWh. In 1985, the consumption dropped to 3.67 g/kWh, which is still unusually high.

EdD should conduct a detailed study of the consumption of lubricants with the aim of redefining maintenance procedures and oil changes, and/or reviewing the technical specifications of the lubricating oils now being used. The specific consumption of lubricants should be brought down to a significantly lower level, to about half the present consumption.

Power Station Operation

In general, the EdD plants are well operated and correctly maintained, and the availability of the equipment is on the whole satisfactory. However, the operation of the stations does not give a clear indication of the availability of each generator or of each station. It is recommended that EdD nclude these statistics in their analyses of performance, and keep track of the long term variation. This will permit both an evaluation of overall production efficiency, and the ready identification of generators which are not running satisfactorily, or which are expensive to maintain.

Energy consumption by auxiliary (in-house) services is a particular problem, and one which should be subjected to close examination. During the last few years this consumption amounted to 7.5 % of electricity produced. Although in 1985 this figure dropped to 6.5 % it still remains too high. However, one reason for this high consumption could be the method of cooling: the Boulaos station uses a dry air cooling system. It is recommended that EdD study the possibility of cooling the engines by other means--perhaps by using a secondary circuit of sea water.

The Cost of New Equipment

In 1984-1985, two 15 MW generators were installed in Djibouti ville as part of the new phase of development of the Boulaos 2 power station. The building which was then constructed holds only the two generators at present, but a further extension is planned for the installation of two more generators.

Based on the figures available, the cost of the last four generators installed at Boulaos was about 143 MFD/MW or approximately $805 US per kW installed.

As far as the Diesel generators in the District centres are concerned, the latest addition (1985-1986) is the station at Dikhil with four generators. The total turn-key cost was 431.2 MFD, or an installed cost of 270 MFD/MW.

This is an unusually high cost for this type of installation and is a result of the kind of contract which was entered into. The cost of the actual equipment, including auxiliaries was about 160 MDF/MW, the remainder being the charges for civil engineering, ground works, and other expenses.

4.3.3.2. The Transmission and Distribution System

The EdD grid systems have three voltage levels : low voltage at 220/380 V, mid-range voltage at 20 kV, and high voltage at 60 kV. By the end of 1985, 193 km of low voltage lines, 202 km of mid-range voltage lines, and one 6 km line of 60 kV were in operation (see Table 4.3.3). Included in the above are two transmission lines of 20 kV totaling 86 km, (Djibouti-Arta 40 km long and Dikhil-Ali Sabieh 46 km long). The rest are distribution networks within the areas supplied with electricity.

The unit length of the networks per GWh consumed is 659 m for transmission lines, and 2,414 m for distribution lines (of which 1,479 m are low voltage and 935 m are mid-range or high voltage). These are rather low figures. For the distribution lines this is due to the small area supplied and the significant consumption of air-conditioning units.

The unit length of the transmission system is particularly low. This is partly explained by the fact that production is entirely from Diesel generators, which are easily adaptable to the demand at each locality.

Table 4.3.3 Transmission and Distribution System

	Dec. 79	Dec. 81	Dec. 83	Dec. 85
High voltage 60 kV				
underground lines, km				6.0
transformer posts (60/20 kV)				2
Mid range voltage 20 kV				
underground lines, km	35.0	51.0	66.9	79.1
lines above ground,km	63.9	63.0	71.2	120.2
lines above ground, insulated, km	2.2	2.5	2.5	2.5
	101.1	116.5	140.6	201.8
Transformer posts				
Public posts	111	115	125	134
Mixed posts	23	30	33	34
Subscriber posts	17	20	21	26
Total number	151	165	179	194
Public posts, MVA	...	36.9	40.9	44.2
Mixed posts, MVA	...	13.8	14.8	15.1
Subscriber posts, MVA	...	7.3	8.0	11.5
		58.0	63.7	70.8
Low voltage				
underground lines, km	27.4	30.7	35.2	40.1
lines above ground, km	134.1	137.8	143.6	153.3
	161.5	168.5	178.8	193.3
Public lighting				
underground lines, km	7.8	12.3	21.6	27.1
lines above ground, km	-	2.2	5.3	5.5
lights (thousands)	0.3	1.9	2.1	2.3
Production of electricity, GWh	102.5	123.4	147.6	164.2
Specific length, km/GWh				
mid range voltage	0.99	0.94	0.95	1.23
low voltage	1.58	1.37	1.21	1.18
Total	2.57	2.31	2.16	2.41

The transformer stations in operation in 1985 consisted of 2 stations 60/20 kV, and 194 stations of 20 kV/low voltage. Of the total, 134 are public, 34 mixed and 26 are subscriber stations. The transformers installed in the mid-range voltage/low voltage stations put out a total power of 70.8 MVA, which shows a correct adjustment of the transformers to the power demand.

In 1985, transmission losses were 12.3 %, about the same as the average over the last five years of 12.9 % (see table A 4.3.3). These losses, while not unusual for well run networks, are still slightly too high, considering the reduced length of the lines as mentioned earlier.

EdD should ensure that they are able to quickly detect saturated areas of the network, and can reinforce them in time. In addition, efforts to prevent the stealing of electricity should be continued.

With regard to the electrical connections, one should note that, despite a certain simplification of the technical norms, the consumer is offered a choice of too many variants. This situation is partly due to the tariff structure in effect which permits a wide range of subscribed power levels commencing with 1 kVA. It should also be noted that monophase connections are available only up to a power of 6 kVA, and triphase connections from 3 kVA upwards.

In order to reduce distribution costs, it is recommended that the diffusion of triphase connections should be limited to consumers who subscribe to the higher levels of power (over 9 kVA), and that the introduction of a monophase connection of 10 or 12 kW should be installed at first only in the zones where the network is sufficiently robust and where the consumers are a homogenous group.

The standards applicable to the connections should be reviewed, and the range of possible connections offered to the consumer should be reduced; for example :

- a monophase connection of 6 kW.
- a monophase connection of 10 to 12 kV, to be only offered in areas where the network is suitably adapted.
- a triphase connection of 18 kW.
- a triphase connection of 36 kW.

- special low voltage connections up to 250 kW, installed on a case by case basis, for very large consumers.

Annex 4.1 shows recent costs for high voltage electrical lines, and the present cost of connections.

4.3.4. The Cost of Electricity Production

In order to analyse the cost of supplying electricity, four categories of electricity supply need to be studied: low and mid-range voltage supply in both the Djibouti network and in the District centres. The calculation of the cost of production of each category is only possible if one can separate the actual expenditures of each sector of activity from the part which is shared.

Since EdD is not equipped with an analytical accounting system, it is obliged to use a rather empirical system, i.e. the disaggregation of expenses is estimated indirectly by analysing the annual accounts of each centre of production.

The overall cost of supplying electricity in 1985 was as follows:

	MDF	%
Proportional costs : fuel and lubricants	1,942	41.4
Direct fixed costs : (of which, personnel)	1,694 (844)	36.1 (18.0)
Financial charges + supplies	1,054	22.5
TOTAL	4,690	100 %

As in all systems based on Diesel production, fuel accounts for over 40 % of the total cost. One can also note the high level of personnel costs which is typical of a relatively small system.

The calculation of costs for each distribution range is carried out by assuming that electricity supplied to the transformer stations of mid-range and low voltage has the same cost, without making the distinction between individual consumer stations, mixed stations, or public stations. At this level, therefore, the cost of production is made up of all expenses including general administrative costs.

The cost of production of low voltage power also includes specific expenses such as the low voltage networks (including the low to mid-range transformers) and the administration of the low voltage subscribers. For 1985, these costs were as follows :

1985 Production Costs, FD/kWh

	Djibouti network	District centres	Aggregate
mid-range voltage	31.67	69.51	32.81
low voltage	35.46	76.72	36.78
Aggregate	33.57	75.87	34.85

4.3.5. Electricity Tariffs

The current tariffs, in force since 14 February, 1983, are shown in Table 4.3.4. The tariff structure is made up of 3 low voltage classes, with various categories, a public lighting tariff, and a mid-range voltage tariff which is different for the Djibouti network and that of the District centres. All tariffs include a fixed price, a function of the power subscribed to, and then block rate charges which vary according to the subscribed power.

The mid-range voltage tariff has a fixed price linked to the power subscribed to by a generally declining block structure which starts, strangely enough, with a very low price block. It would seem that this structure was introduced for certain specific consumers (e.g. for lighthouses). The energy cost per block shows a progressive reduction in cost depending on the duration of utilization.

There is a marked difference in energy prices between Djibouti and the District centres: prices are 50 % higher in the Districts.

The principal objection to the mid-range voltage tariff is that it is higher than the low voltage tariff which is a serious distortion of the tariff structure. The average sale price of mid-range voltage is higher than that of the low voltage. For the District centres, even the prices per block are higher in all the mid-range voltage cases.

This anomaly obviously produces unusual consumer responses: clients using large amounts of power prefer to be supplied with low voltage power because, not only do they avoid having to install their own transformer stations, but they also pay a lower tariff.

Low voltage tariffs are made up of two categories depending on the type of consumer : domestic or non-domestic. For non-domestic consumers, there are two tariffs: one simple binominal tariff, which is not very widespread as it is the most expensive; and a tariff of 4 blocks of which 3 decline in price while the fourth is slightly more expensive.

This tariff is unnecessarily complicated and even includes two variants, depending on the presence of a maximum power indicator on the electricity meter of each subscriber.

For domestic consumption, the tariff has two block rates and a fixed cost. The two block rates are quite similar. The most noticeable characteristic of this tariff is the significant difference between prices per kWh for power consumers of 1 kW and the others. The very low price allowed to 1 kW power consumers has encouraged the proliferation of such subscribers, with income levels well above those which one would normally consider modest.

Among these 1 kW subscribers, one finds several hundred or more who are using an amount of power far above that which is physically possible. EdD should eliminate this abuse by using a proper system of control on the cut-out switches. The problem is to identify the genuine low income consumers, and to decide whether or not to provide subsidies.

Any new tariff structure should be carefully studied, and its financial impact on low income subscribers should be fully considered.

Table 4.3.4. (a) The Present Tariff Structure

TARIFFS LOW VOLTAGE	Fixed cost FD/month	Consumption block structure	Price FD
I General (code 03)			
PS < 36 kVA	350 FD		
PS > 36 kVA	38 FD/kVA	Unique	46
or	46 FD/kVA		
II Domestic			
Code 01 - PS = 1 kVA	360 FD	1st : 90 kWh	29
		2nd : the rest	25
Code 02 - PS = 3 kVA	560 FD	1st : 90 + 5.PS	37
6 ...	630 FD	2nd : the rest	35
9 ...	770 FD		
> 9 ...	880 FD		
III Degressive (code 04)		1st : 75.PS	46
PS < 10 kVA	300 FD	2nd : 90.PS	42
PS > 10 kVA	880 (PS-10)	3rd : 100.PS	37
		4th : the rest	43
III 2nd Degressive (code 05)		1st : 95.PS	46
PS < 8 kW	300 FD	2nd : 110.PS	42
PS > 8 kW	1100 (PS-8)	3rd : 125.PS	37
		4th : the rest	43
IV Public lighting (code 08)		unique	36
V District centres			
ARTA, OUEAH (code 06)			
PS < 36 kVA	350 FD	unique	46
PS > 36 kVA	38 FD/kVA		
(code 07) Ali Sabieh, Dikhil, Obock, Tadjourah.			
PS < 36 kVA	350 FD	unique	46
PS > 36 kVA	38 FD/kVA		
Code 09 : work sites			
PS < 18	5000 FD		
PS = 18 - 36	10000 FD	unique	46
PS > 36	350 FD		

Note: PS is power subscribed to.

Table 4.3.4 (b) The Present Tariff Structure (continued)

TARIFFS: MID-RANGE VOLTAGE

Fixed price : FD/month

for the first 8 kW		300 FD
first block	8-500 kW	1100 FD/kW
second block	501-900 kW	1045
third block	901-1300 kW	990
forth block, above 1300 kW		935

Price of energy: FD/kWh

	DJIBOUTI ARTA, OUEAH	ALI SABIEH, DIKHIL OBOCK, TADJOURAH
first block	32.00	46.00
second block	26.10	39.10

Size of the first block: kW/month

for PS < 200 kW	250.PS
for 201 to 500 kW	200.PS
for PS > 500 kW	175.PS

Minimum consumption KWh/year

800 . PS for teaching institutions
1200 . PS for all other subscribers

(to be revised in the near future)

PS = Power subscribed to.

In the District centres there is only one low voltage tariff, with no distinction made between domestic and non-domestic consumers. This tariff is set in the same way as the general tariff for Djibouti ville, but with a lower energy price which is about the same as the domestic tariff in Djibouti ville for PS > 3 kW.

The only exceptions are the centres at Arta and Oueah, where prices are much higher, equal to those of the general tariff.

Arta and Oueah are supplied by Djibouti's network and should therefore have the same tariffs as other subscribers of this network.

The average prices paid by low voltage subscribers according to the different tariffs, are shown in Figure 4.3.5. The declining average price as a function of the duration of power utilized, due to the declining unit cost, is common to all tariffs.

The management of the present tariff system suffers from several practical difficulties, notably the difficulty of checking the general subscriber and applying the appropriate tariff. The general tariff has therefore been shunned by consumers, who have made every effort to become part of the groups enjoying a lower tariff.

Another problem -- as yet unresolved -- concerns the control of the power subscribed to. Although subscribers have cut-off switches installed, EdD has been unable to ensure their proper operation. Problems also remain with the supervision of the electricity meters.

4.3.6. The Cost and Sale Price of Electricity

Table 4.3.5 gives a general view of the principal data concerning electricity production and sale in Djibouti.

From an economic standpoint, one should note that the present tariffs appear to be adequate, as is confirmed by a comparison of the cost of production and the sale price. In 1985, electricity was sold at a slightly higher price than its production cost in Djibouti ville, while in the District centres the production cost was approximately double the sale price.

In general, the surfeit in Djibouti compensated for the losses in the District centres, and EdD's accounts for 1985 resulted in a profit of 332.5 MDF, or 6.6 % of total revenues for the period.

The evident deficit in the District centres should, however, be considered as a serious problem, and a solution should be found. Should one try to balance the accounts of each District, or should one accept that, with such a complicated industry, some parts of the system remain in permanent deficit ?

Table 4.3.5 Principal Indicators of the Electricity Sector (EdD) 1985.

	Djibouti MWh	Djibouti %	District centres MWh	District centres %	Total MWh	Total %
Production					164200	100
Energy emitted		100		100		
Total energy delivered	130513		4069		134582	
- mid range voltage	65014		483		65497	
- low voltage	65499		3586		69085	
<u>Cost of Production</u>	FD/kWh		FD/kWh		FD/kWh	
- mid range voltage	31.67		69.51		32.81	
- low voltage	35.46		76.72		36.78	
Total mid + low	33.57		75.87		34.85	
<u>Average sale price</u>						
- mid range voltage	38.23		54.96		38.35	
- low voltage	36.09		40.90		36.34	
	37.16		42.57		37.32	

REFERENCES

4.1 The discussion of charcoal production is taken from the report by Dominique Briane: "Etude sur les combustibles domestiques dans les Districts de Djibouti", ISERST, 1986.

4.2 The discussion of electricity is based on the report by Mihai Petcu: "Perspectives de devèloppement du système électrique et tarification de l'électricté", ISERST, 1986.

ANNEX 4.1 RECENT POWER LINE AND INSTALLATION COSTS FOR EDD

The 60 kV installation is the only one in Djibouti. It was put into operation in 1984-1985 during the extension of the Boulaos power station. There is a 60 kW transformer post installed in the power station, which takes the output from the 2 new generators and an underground cable, which links the Boulaos station to a post supplied by the Marabout power station about 6 km away.

It is a permanent connection embedded in sand, 3 x 1 x 400 mm2, which will probably never be repeated. The cost was 356.3 MFD for the line and 175.5 MFD for the 60/20 kV post at Marabout, equipped with a 36 MVA transformer. The 60 kV post at Boulaos, also equipped with a 36 MVA transformer, cost 221 MFD.

The 20 kV transmission line between Dikhil and Ali Sabieh was a turn-key contract, and its total cost was 238.4 MFD. Taking into consideration the distance of this line, 46 km, the cost per kilometre of 5.18 MFD/km is relatively high. EdD now has the technical capability to install power lines and transformer posts, and in the future should not have to resort to turn-key contracts, which are always more costly. The cost of the 20 kV lines installed might have been approximately 20 % less expensive, that is about 4 to 5 MFD/km.

For building sites a very practical system has been developed which consists of an installation price of 24,000 FD for PS < 18 kVA or 48,000 FD for PS = 24 to 36 kVA, together with a rent of 6,000 FD/month or 12,000 FD/month respectively.

The cost of the connections is studied and brought up-to-date periodically by the Transmission and Distribution Service of EdD. According to a recent study (7 August 1986), the prices were as shown in Table A 4.1.1. overleaf.

The connection charges include the cost of reinforcing the lines if the power is increased. The charges also apply to communal establishments, workshops, etc.

Table A 4.1.1. Cost of Electricity Connections

Ordinary connections of less than 50 m :	
- monophase, 1 kVA	25,000 FD
- monophase, 3 to 5 kVA	40,000 FD
- triphase, 6 to 12 kVA	60,000 FD
- triphase, 15 to 18 kVA	75,000 FD
- triphase, 18 to 36 kVA	180,000 FD

Connections of over 50 m :

- in addition to the above prices, a supplement of 2,400 FD per metre is charged based on the length of the extension from the last post to the delivery point, independent of subscribed power.

ANNEX 4.2 THE STRUCTURE OF ELECTRICITY CONSUMPTION

In order to describe the structure of electricity consumption in more detail, the subscribers have been grouped according to their size and category. Table A 4.2.5 (a) shows the consumption of the low voltage subscribers for the Djibouti network, and Table A 4.2.5 (b) shows the consumption of the low voltage consumers for the District centres.

It can be seen from these data that domestic consumers make up 90.7 % of all low voltage users and their consumption is 87.1 % of total low voltage consumption.

Among the domestic consumers, 65 % subscribe to a 1 kW power supply, and thus benefit from a reduced tariff. One should note, however, that this subscribed power is not always correct. A more detailed analysis of consumption reveals that a large number of these subscribers (around 15 %) are clearly using higher levels of power.

For the District centres one has only statistics for the power subscribed, with no knowledge of whether the consumers are domestic or professional. The consumption per consumer is slightly higher in the District centres than in Djibouti, especially for 1 kW subscriptions (this could be due to a large proportion of irregular consumers, taking power at a level higher than that to which they have subscribed).

To eliminate, at least in part, these irregularities in power subscribed, the statistical distribution of monthly consumption for consumers subscribed to the same power has been studied. The results of this analysis are shown in Figures A 4.2.1 (a) and (b) for 1 kW and 6 kW consumers respectively.

For 1 kW subscribers one can see that the average monthly consumption in summer (shown in Table A 4.2.5 a) of 206 kWh/month is only reached by approximately 36.5 % of subscribers, whereas the median figure is 160 kWh/month. The most frequent levels of consumption of these subscribers is between 30 and 180 kWh/month as can be seen from Figure A 4.2.1 (a). In terms of energy consumed, therefore, about 20 % is due to subscribers in fact consuming more than 1 kW.

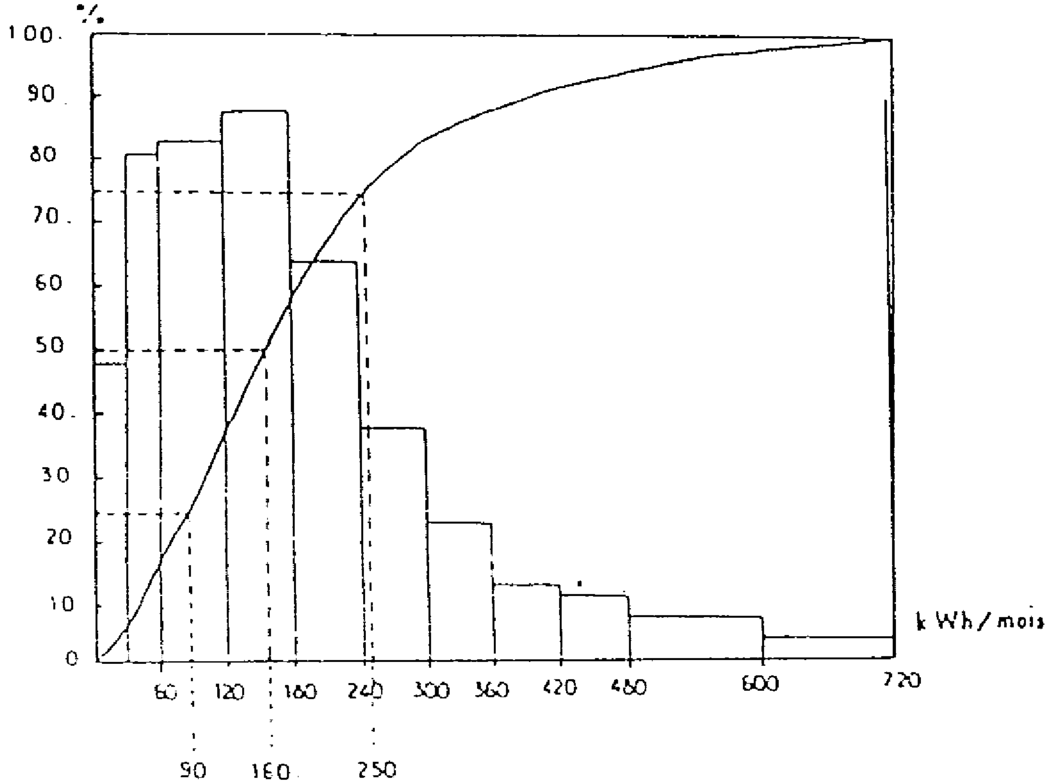
If we consider that the average consumption of real 1 kW subscribers is quite close to the median, for the 6 kW subscribers, cases of fictitious subscription appear to be less common, although they do still occur, as one can see when examining the computer results. In fact, the median figure and the average are practically the same for these subscribers.

A review of Figures A 4.2.1 (a) and (b) illustrates another characteristic which is important for the study of the tariffs: the seasonal fluctuations in the consumption of energy by different categories of consumers. For small consumers, the ratio between summer and winter consumption is a factor between 1.5 and 2. However, for the 6 kW consumers the ratio is between 3 and 4.

For domestic consumers subscribed to higher power levels, the difference in consumption is even larger. It is interesting to note that this characteristic is more closely linked to the level of monthly consumption than to the actual power subscribed to. This can be seen in Figure A 4.2.1 (b) when comparing the forms of the two functions.

Table A 4.2.6 shows the consumption profile for each branch of economic activity for subscribers of over 36 kW, supplied with either mid-range or low voltage. This profile, which reflects the nature of activity of the subscriber, does not permit the identification of homogenous consumer groups, because, for example, the "administrative" group, which represents 30 % of consumption, includes all types of consumers : offices, houses, technical services, hospitals, etc... which have very different types of consumption. Knowledge of the form of consumption for each economic branch of activity is essential for the projection of future electricity demand.

PS = 1 kW Hot Season



PS = 1 kW Cool Season

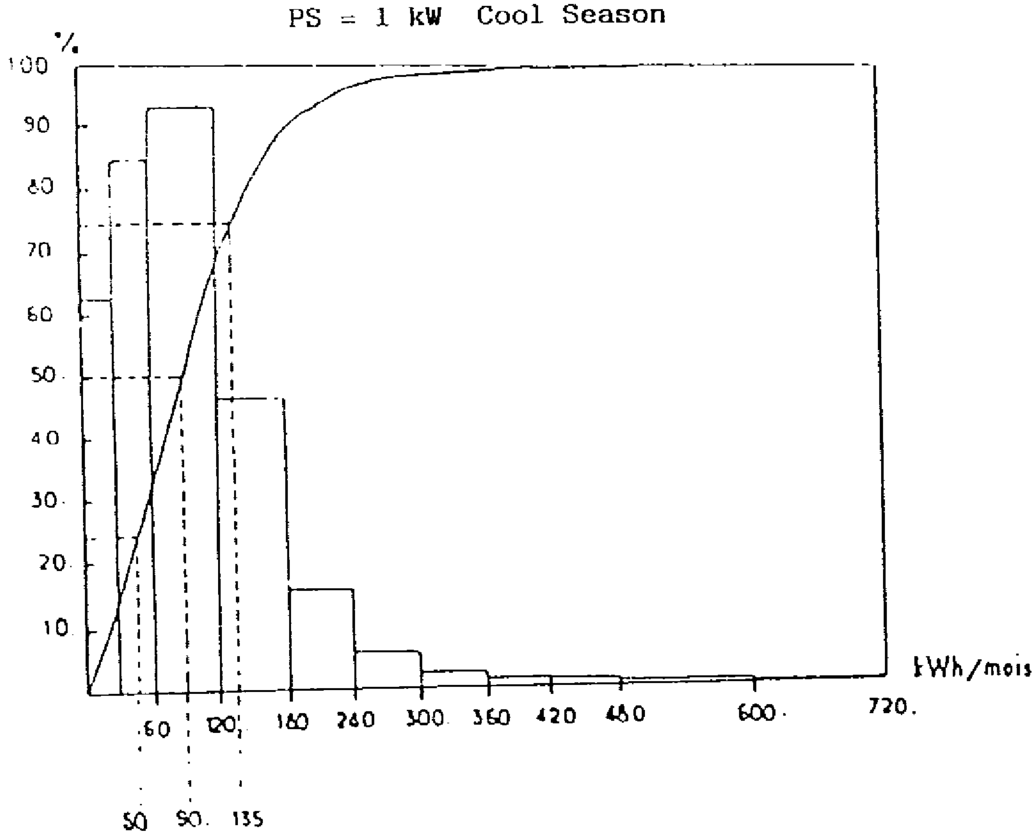


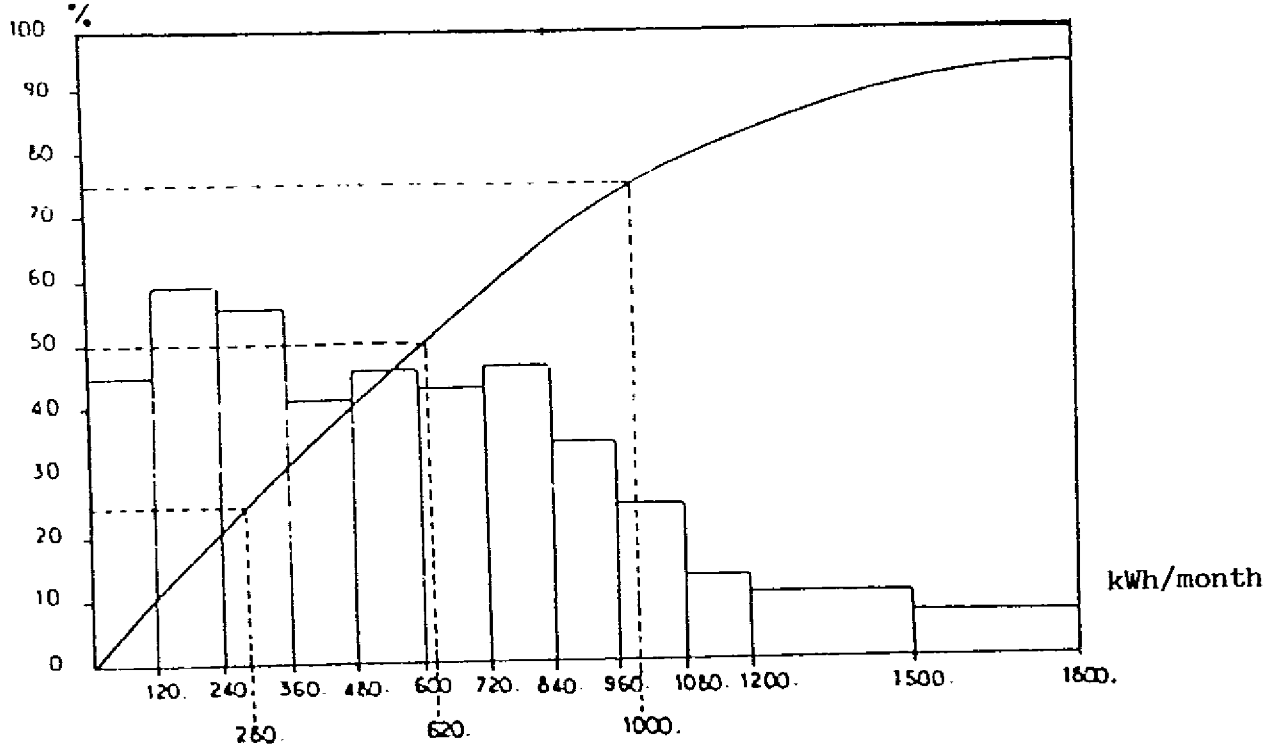
Figure A4.2.1. Frequency Distribution of Monthly Electricity Consumption for consumers subscribing to 1 kW.

In the hot season :

- 75% of subscribers consume less than 250 kWh/month
- 50% of subscribers consume less than 160 kWh/month
- 25% of subscribers consume less than 90 kWh/month

In the cool season consumption is 135,90 , and 50 kWh/month respectively. Number of subscribers = 8380 (100%)

PS = 6 kW Hot Season



PS = 6 kW Cool Season

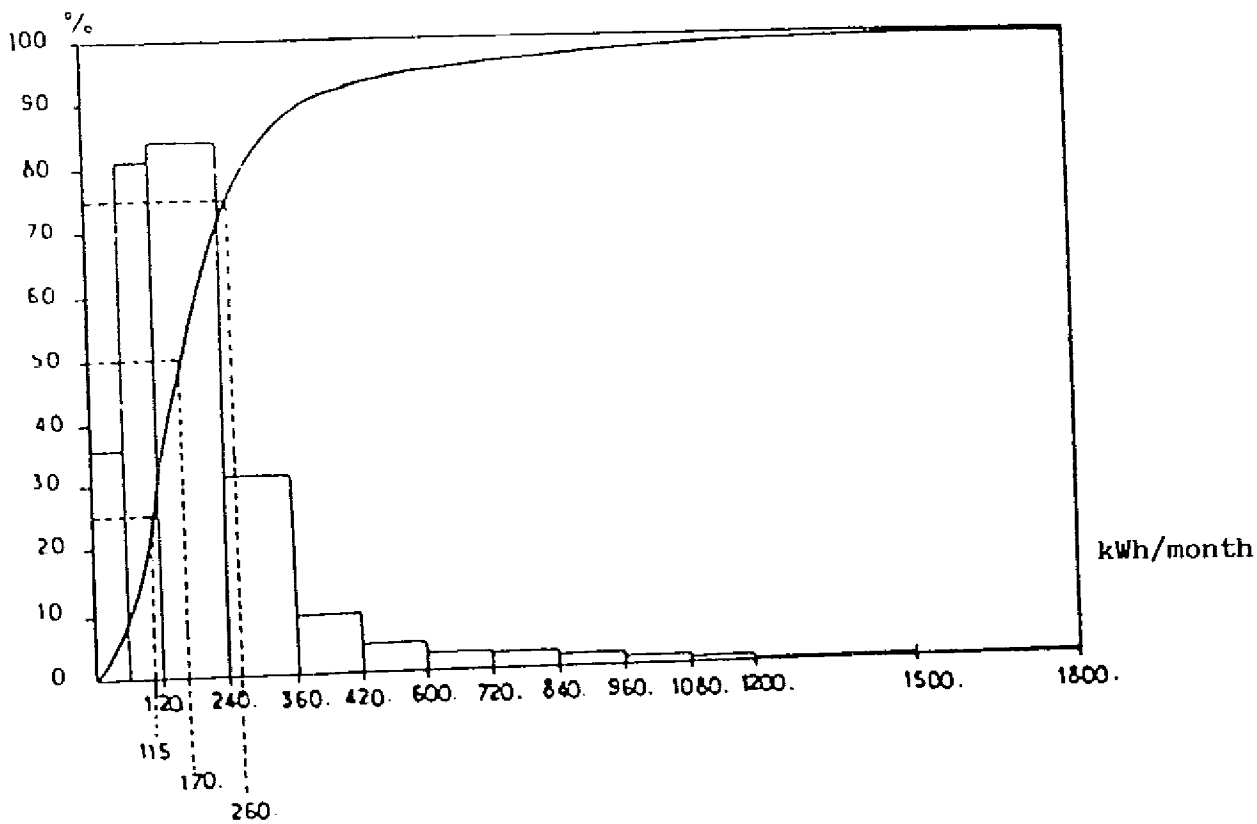


Figure A4.2.2. Frequency Distribution of monthly Electricity Consumption by Domestic Consumers, Power subscribed 6 kW.

In the hot season :

- 75% of subscribers consume less than 1000 kWh/month
- 50% of subscribers consume less than 620 kWh/month
- 25% of subscribers consume less than 280 kWh/month

Table A 4.2.1. Evolution of the Production of Electricity, GWh

	Principal network Djibouti-Arta	Ali Sabieh	Dikhil	Obock	Tadjourah	Sub total District centres	TOTAL
1971	43.204						
1972	48.463						
1973	56.342						
1974	61.584						
1975	72.983						
1976	82.030						
1977	89.070						
1978	92.800						
1979	102.500						
1980	113.658	0.450	0.911	0.334	1.343	3.038	116.696
1981	119.505	0.544	1.036	0.463	1.889	3.932	123.437
1982	126.563	0.599	1.169	0.508	2.053	4.329	130.892
1983	142.188	0.813	1.340	0.804	2.413	5.370	147.558
1984	140.863	0.952	1.347	0.536	2.463	5.298	146.161
1985	158.827	0.911	1.190	0.640	2.677	5.418	164.245
Average annual rate of growth (percent):							
1971-80	11.3						
1980-85	6.9	15.1	5.5	13.9	14.8	12.3	7.1

<u>Contribution</u>

	1980	1985
Main network	97.4 %	96.7 %
District centres	2.6 %	3.3 %
	100.0 %	100.0 %

Table A 4.2.2. Production of Electricity and Peak Demand in the Principal Network 1971-1985

	Production GWh/an	Energy emitted GWh/an	Consumption by auxiliaries %	Peak demand MW	duration utilization hr/yr
1971	43.204	41.676	3.54	9.00	4800
1972	48.463	46.694	3.65	10.25	4728
1973	56.342	54.229	3.75	12.00	4695
1974	61.584	59.450	3.46	14.30	4306
1975	72.983	70.641	3.21	15.10	4833
1976	82.030	77.400	5.64	17.10	4797
1977	89.070	82.620	7.24	18.15	4907
1978	92.800	86.450	6.84	19.70	4711
1979	102.500	95.060	7.26	22.10	4638
1980	113.658	104.810	7.78	23.95	4746
1981	119.505	110.913	7.19	24.80	4819
1982	126.563	115.049	9.10	25.95	4877
1983	142.188	131.573	7.46	28.40	5007
1984	140.863	130.257	7.53	31.50	4472
1985	158.827	148.405	6.56	32.15	4940
81-85	687.946	636.197	7.52		

Table A 4.2.3. Consumption of Electricity and Losses in the Principal Network, 1971-1985.

	Energy emitted GWh	------ Consumption, GWh ------- low and mid range voltage, PS>36 kW	low voltage PS<36 kW	TOTAL GWh	Distribution losses, %
1971	41.676	16.514	20.326	36.840	11.6
1972	46.694	18.728	23.427	42.155	9.7
1973	54.229	22.006	25.706	47.712	12.0
1974	59.450	24.963	27.600	52.563	11.6
1975	70.641	32.763	31.399	64.162	9.2
1976	77.400	36.078	33.014	69.092	10.7
1977	82.620	39.688	34.105	73.793	10.7
1978	86.450	41.466	34.472	75.938	12.2
1979	95.060	47.662	41.124	88.786	6.6
1980	104.810	47.091	44.653	91.744	9.7
1981	110.913	48.720	48.177	96.897	12.6
1982	115.049	53.268	52.287	105.555	8.3
1983	131.573	54.504	55.613	110.117	12.5
1984	130.257	55.368	55.599	110.967	14.8
1985	148.405	65.014	65.499	130.513	12.1
71-75	272.690	114.974	128.458	243.432	10.7
		47.2 %	52.8 %	100 %	
76-80	446.340	211.985	187.368	399.353	10.5
		53.1 %	46.9 %	100 %	
81-85	636.197	276.874	277.175	554.049	12.9
		50.0 %	50.0 %	100 %	

Table A 4.2.4. Seasonal Variation in the Production of Electricity in 1985

Month	Production MWh	Production %	Peak demand MW	Peak demand %	Load factor
J	7897	5.0	14.70	46	0.722
F	7383	4.6	14.60	45	0.753
M	9437	5.9	18.90	59	0.671
A	12195	7.7	21.80	68	0.777
M	15497	9.8	31.50	99	0.661
J	17589	11.1	32.15	100	0.760
J	18810	11.8	31.75	99	0.796
A	18906	11.9	31.75	99	0.800
S	17796	11.2	31.40	98	0.787
O	14227	9.0	25.80	80	0.741
N	10383	6.5	18.20	57	0.792
D	8707	5.5	16.30	51	0.718
Year	158827	100.0	32.15	100	0.764

Table A 4.2.5 Structure of the Consumption of electricity

a) Low voltage subscribers in Djibouti

Tariff	PS	number of subscribers	number irregular	Total energy (winter) MWh/month	average consumption kWh/month
GENERAL	1	468	5	75	160
	3	351	1	85	243
	6	202	2	74	366
	9	148	2	107	723
	12	47		36	772
	15	27		39	1457
	18	147		174	1186
	21	3		5	1530
	24	25		47	1866
	30	12		29	2455
	36	38		88	2324
		1468		759	517
DOMESTIC	1	9569	340	1973	206
	3	1584	9	669	422
	6	1580	7	980	620
	9	1268	4	1019	804
	12	184		170	924
	15	88		150	1701
	18	412		556	1350
	21	1		1	800
	24	2		1	570
	30	3		13	4213
	36	20		74	3699
sub total	3-36	5142		3633	707
DIGRESSIVE	9	2		-	148
	12	1		-	
	15	3		2	811
	18	9		23	2503
	24	3		21	7125
	30	7		12	1743
	36	3		10	3300
		28		68	2428
GROUP TOTAL		16207		6433	397

Table A 4.2.5 b) Low Voltage Subscribers in the District centres

Subscribed power (kW)	1	3	6	9 to 36
Number of subscribers	1020	278	149	115
Classed by monthly winter consumption (kWh) :				
- 25 % consume less than	100	180	240	...
- 50 % consume less than	190	300	480	...
- 75 % consume less than	360	660	1140	...

Table A 4.2.6 Mid Range Voltage Consumption by Activity, September 1986

Type of activity	monthly consumption MWh	%
Administration and public service	1934.2	30.7
Commerce, banks, insurance	463.3	7.4
Hotels, bars, restaurants	414.9	6.6
Industry	487.4	7.7
Agriculture and fishing	97.6	1.6
Water pumping	456.9	7.3
French army	2265.6	36.0
Public lighting	173.9	2.7
	6293.8	100.0

Table A 4.2.7 Average Monthly Production Power Factor

Month	1981	1982	1985	1986	Average value
J	0.841	0.848	.....	0.848	0.846
F	0.836	0.857	.....	0.848	0.847
M	0.838	0.868	.....	0.852	0.852
A	0.851	0.858	.....	0.875	0.859
M	0.867	0.894	.....	0.858	0.873
J	0.875	0.903	0.892	0.852	0.880
J	0.888	0.907	0.877	.....	0.891
A	0.877	0.918	0.903	.....	0.899
S	0.878	.....	0.889	.....	0.883
O	0.857	.....	0.866	.....	0.862
N	0.842	.....	0.862	.....	0.852
D	0.831	.....	0.838	.....	0.834

Table A 4.2.8 Consumption of Fuel and Lubricants in EdD Power Stations

POWER STATIONS IN DJIBOUTI	1983	1984	1985
Diesel consumption, tonnes	1293	761	1467
Fuel oil consumption, tonnes	34651	34364	35217
	35944	35125	36684
Consumption lubricants, tonnes	643.7	675.8	683.7
Production of electricity, GWh	142.188	140.863	158.827
Specific consumption, g/kWh			
- fuel	252.6	249.4	231.0
- lubricants	53	4.79	3.67
DISTRICT CENTRES			
Diesel fuel consumption, tonnes			
- Tadjourah	654.5	671.5	718.7
- Dikhil	392.0	402.2	402.3
- Ali Sabieh	288.0	370.2	295.1
- Obock	248.6	234.2	220.0
	1583.1	1678.1	1636.1
Production of electricity, MWh			
- Tadjourah	2413	2463	2677
- Dikhil	1340	1347	1190
- Ali Sabieh	813	952	911
- Obock	804	536	640
	5370	5298	5418
Specific consumption, g/kWh			
- Tadjourah	271.2	272.6	268.5
- Dikhil	292.5	298.6	338.1
- Ali Sabieh	354.2	378.4	323.9
- Obock	309.2	436.9	343.8
	294.8	316.7	302.0

C H A P T E R 5

FINAL ENERGY

Final energy is the name used to describe the energy that is actually or finally used to carry out a particular task. Fuelwood burned in a 3-stone fire, kerosene burned in a small kerosene stove, liquified propane gas (LPG) used in a gas stove, or electricity consumed in an electric stove, are all examples of different fuels being used to perform a specific task--in this case cooking.

For some uses (sometimes called end-uses), several sources of energy can be used. Substitution among the different sources of energy is therefore possible. The fuels used for cooking cited above are an obvious example.

In other cases, however, the type of energy required for a particular task cannot be easily substituted; electricity, running a television set for instance. But even if substitution by another fuel or source of energy is not possible, there are often other steps which can be taken which will reduce the consumption of energy.

The aim of this chapter is to examine the possibilities for interfuel substitution, and for improving the efficiency of energy use, in a number of end-use applications.

5.1. SUBSTITUTABLE ENERGY

5.1.1. Cooking

Cooking is one of the end-uses where the possibilities for interfuel substitution are numerous. In Djibouti, several types of fuel are used for cooking: fuelwood (and its derivative charcoal), kerosene (more commonly but erroneously called "gas"), LPG (a monopoly of the Shell petroleum company), and electricity (used only in a very limited number of housholds).

The range of possible interfuel substitutions is discussed below.

5.1.1.1. Fuelwood

a) Fuelwood - kerosene : The shift from cooking with wood on a 3 stone fire to cooking with kerosene using a metal stove, generally occurs as a matter of course in households moving to the urban centres.

Their distance from the areas where wood is collected, and the high cost of fuelwood, are the main factors that prompt households to choose kerosene for cooking.

However, in some districts, notably the District of Tadjourah where fuelwood is still plentiful and available at an affordable price, a large part of the population still cooks with wood.

Is the use of fuelwood for cooking depleting forest resources, or is the biomass resource base sufficient to allow the use of fuelwood for cooking, and even permit the use of wood to spread to a greater number of households? These questions could be answered by a study of fuelwood resources, (see, for example, paragraph 10.3).

This study would also permit planners to decide on the appropriate strategy to promote the appropriate interfuel substitutions.

b) Fuelwood - L.P. Gas

The use of LPG requires a gas stove whose cost is generally too high for the majority of families with low or middle incomes.

Moreover, cooking on a gas stove is quite different to cooking over a wood fire, and the transition is not always easy. It therefore seems unlikely that one would see a major substitution of LPG for fuelwood without the intermediate shift from fuelwood to kerosene.

c) Fuelwood - electricity

Electric cookers are not very common in Djibouti. The direct shift from fuelwood to electricity for cooking therefore seems improbable.

5.1.1.2. Kerosene

a) Kerosene - firewood : This substitution appears to reverse normal technical progress, but if a study of forest resources shows that these resources are sufficient, this substitution could take place in a number of households.

b) Kerosene - LPG : Rather than referring to substitution, it would be more appropriate to speak of combined use, since families that opt for LPG stoves often keep kerosene stoves for cooking certain types of dishes.

c) Kerosene-electricity : Refer to fuelwood - electricity.

5.1.1.3. L.P. Gas

Only the LPG-electricity substitution is considered in this paragraph. This substitution will probably remain marginal since electricity is used for cooking in only a very small number of households.

5.1.1.4. Electricity

Refer to the paragraph above.

5.1.2. Lighting

5.1.2.1 Fuelwood

For nomadic populations the traditional means of lighting is the wood fire. With improvements in the distribution of kerosene it is possible that kerosene lamps might slowly replace wood fires for lighting.

5.1.2.2. Kerosene

Urban households which do not have electricity provide illumination with kerosene lamps. This means of lighting is quickly replaced as soon as the house is connected to the electricity supply. This possible interfuel substitution is important.

5.1.3. Refrigeration

Refrigeration, together with air conditioning, is one of the end-uses which consumes the most energy. This high consumption occurs because only "western" under-insulated refrigerators are available, and refrigerators are often placed in open and very hot courtyards, most of the time directly in the sun.

Apart from a few isolated cases of substituting traditional electrical supply with solar electricity, mainly in rural dispensaries, it seems most unlikely that one will see any significant substitution of the present type of refrigerators in the near future.

However, if solar thermal refrigeration (absorption systems), are ever developed to the point where they are a realistic alternative, it would be interesting to install a number of prototype systems in Djibouti in order to evaluate the feasibility of this technology.

5.1.4. Air-conditioning

The problem is identical to that of absorption refrigeration systems. In the event that this technology matures, it would be useful to establish a number of prototype installations with a view to possible future substitution.

5.1.5. Transport

5.1.5.1. Petrol - Diesel : The tariff structure of motor fuel prices is at the present time very much to the advantage of Diesel fuel, in an approximate ratio of 1 to 2 (68 FD for a litre of Diesel, 132 FD for a litre of super). Buyers are therefore encouraged to purchase Diesel engine vehicles, often 4-wheel drive, whose fuel consumption is slightly higher than that of petrol vehicles.

This situation will evolve in response to the fuel tariff structure. Thus, one could see a petrol-Diesel substitution, or Diesel-petrol, depending on which way fuel prices change relative to each other.

5.1.5.2. Diesel - Petrol

The same as the paragraph above.

5.1.5.3. Sea - road

We are not dealing here with a direct interfuel substitution, but rather with a shift in the mode of transport which could result in interfuel substitution.

The Route de l'Unité, now under construction, will link Djibouti ville to Tadjourah by 1988, and will then continue to Obock. Djibouti ville will then be less than 2 hours by road from the Northern districts, and there is likely to be a competition between the road and sea routes for the transport of pasengers and goods, including the transportation of Tadjourah's mineral waters.

The Route de l'Unité is an important element in national development which now needs to be taken into account.

5.1.6. Water pumping

Water pumping for irrigation, for livestock, or for the needs of nomadic populations, is mostly carried out using surface mounted motor-pumps, or small generating sets providing power to electric submersible pumps.

Over the last few years, the introduction of solar pumps in several locations in Djibouti has demonstrated the feasibility of this technology. ISERST has trained and supported a team of technicians able to intervene quickly and competently in the event of technical problems.

During 1987, about twenty new solar pumps, financed by the Association Francaise pour la Maitrise de l'Energie (AFME), the Fonds d'Aide à la Coopération (FAC), and the United States, will be installed. There is every indication that this development will continue, and that the contribution of solar energy for water pumping will become more than marginal in the mid term.

The development of wind energy could also be important since the meteorological data indicates an important windpower potential. There are currently 5 large windmills in operation, as well as several smaller machines.

For a number of reasons, notably because of insufficient surveys on wind patterns and on the hydrology of the sites, a number of the windmills have had to be relocated to more favourable sites.

In early 1987, ISERST, with logistical and technical support from the French Army, moved 3 of the largest windmills to new sites where they are now in operation.

A well-organized program of maintenance and supervision could facilitate the appropriate development of this mode of water pumping which, together with solar energy, could lead to a significant role for these renewable energy technologies.

5.1.7. Fishing

The fleet of fishing boats consists of about 80 vessels. The Fishing Service is considering gradually replacing the gasoline engines in the boats with Diesel engines -- 10 engines are scheduled to be replaced in 1987 for example.

This petrol-diesel subtitution will be accompanied by the replacement of the present hulls by lighter plastic hulls. A power limit will also be imposed on engine size.

5.1.8. Industrial Process Heat

The use of process heat in the industrial sector is limited.

However, the dairy consumes about 3,000 litres of fuel a month for the generation of steam used in washing, pasteurization and sterilization. The exceptional solar energy found in Djibouti could reduce this energy consumption considerably by pre-heating the water using solar collectors.

Other industries or communities may also be able to take advantage of solar energy for heating water.

It should be noted that solar energy technology, widely used in many countries for domestic water heating, is not applicable to Djibouti, since urban water arrives at the tap at a temperature of 35°-40°C. It does not therefore need to be pre-heated.

5.1.9. Summary

Table 5.1.1. summarizes the possible substitutions discussed above, and indicates the status of each of the options.

Table 5.1.1 Final Energy -- Possible Substitutions

	Energy current	Energy possible	Substitution	Comments
COOKING	wood	kerosene	N	urban areas
		LPG	M	
		electricity	I	
	kerosene	wood	M	urban areas
		LPG	N	
		electricty	I	
	LPG	electricity	M	
	electricity	LPG	M	few electric stoves exist
LIGHTING	wood	kerosene	N	urban areas
	kerosene	electricity	N	urban areas
REFRIGERATION	electricity traditional	solar energy	M	photovoltaic (dispensaries)
			E	absorption
AIR CONDITIONING	electricity	solar energy	E	absorption
TRANSPORTATION	gasoline	Diesel fuel	N	according to price structure
	Diesel fuel	gasoline		
	maritime	road	N	transport to and from North via Route de l'Unité
WATER PUMPING	Diesel fuel	solar energy wind energy	N	
FISHING	gasoline	Diesel fuel	N	in progress
INDUSTRIAL PROCESS HEAT	fuel oil	solar energy	M	heating or pre-heating of water

E : experimental, I : improbable, M : marginal, N : normal

5.2. NON SUBSTITUTABLE ENERGY

The preceding section discussed a number of possibilities for interfuel substitution among the different forms of energy used in a variety of end-uses.

In parallel with these substitutions, which would lead to a significant change in the pattern of national energy consumption, there are a number of techniques capable of modifying, not so much the pattern, but the level itself of energy consumption.

5.2.1. Cooking

Traditionally, the nomad women, or those living in the larger villages, use stoves built with 3 large stones. The stones support the cooking pot which is heated by a wood fire.

This technique, which is very common in the developing countries, has a very low energy efficiency (about 15 %). The fire is exposed to the wind, and is difficult to control and adjust; e.g. adjusting the distance between the pot and the fire, or the size of the fire, controlling the flames, etc.

There are several ways to improve the efficiency of this simple stove, and thus to reduce the consumption of fuelwood. An efficient mud stove would seem well suited for Djibouti. The design is simple and requires only sand and clay. These materials are abundant in Djibouti. The construction of the stove does not therefore entail any expense.

Built around the 3 stones which are retained from the initial stove, the construction of the improved stove involves building a ring of clay around the pot which is to be used. The method of construction is presented in more detail in annex 9.3.

This type of stove, if constructed and used properly, is twice as efficient as the 3-stone fire.

In addition to efforts aimed at improving the efficiency of the traditional 3-stone fire, ISERST is considering launching a program aimed at improving the efficiency of charcoal production in Djibouti.

The charcoal-making technique used at the present time starts with the lighting of an open wood fire. After burning for some time, the fire is then smothered by covering it with a layer of soil. This method produces charcoal of varying and generally inferior quality, and the energy efficiency of the technique is very low--in the region of 22 %.

An improved charcoal-making technique has been successfully developed by the technicians at ISERST. This technique doubles the energy output of the carbonization process, and requires only a small investment for the purchase of corrugated sheeting. This method is described in greater detail in annex 9.6.

The new technique will be demonstrated to charcoal-makers in the different regions of the country. If widely adopted in Djibouti, the technique will significantly reduce the consumption of wood used for the production of charcoal.

5.2.2. Lighting

5.2.2.1. Incandescent Lighting

Incandescent lights are mostly used in the residential sector. The use of incandescent lamps varies appreciably from one category of consumer to another. For example, the 1 kVA and 3 kVA consumers--those with the lowest incomes--possess twice as many fluorescent lights as incandescent lamps; while in the higher-income households, the number of incandescent lamps is greater.

According to a recent survey of consumers, it is the purchase price of the fluorescent light fittings (around 2,000 FD for the fixture, starter and tube), which seems to be the main obstacle to the more widespread use of fluorescent lighting in the more modest households.

There is therefore a significant opportunity for saving energy in this particular application, since the switch from incandescent lighting to fluorescent lighting results in an economy of about 70 % for the equivalent luminous flux.

5.2.2.2. Street Lighting

The majority of the street lights in Djibouti are mercury vapour lamps. These lamps have a slightly lower electrical consumption than incandescent lamps, but a higher consumption than high- or low-pressure sodium lamps.

For an equivalent luminous flux, the switch to high-pressure sodium lamps would permit a reduction in the consumption of electricity of nearly 50 %. However, although the substitution of high-pressure sodium lamps for mercury vapour lamps is taking place, the authorities responsible for street lighting have indicated that they prefer to increase the luminous flux of the lamps while retaining the same electrical power.

Such a substitution would not lead to an absolute saving of energy since the consumption of electricity would remain the same. However, the quality of the street lighting would be much improved.

5.2.3. Refrigeration

Section 5.1.3. pointed out that energy for refrigeration is a significant part of household energy consumption, often as a result of placing the refrigerator in an open courtyard in the full sun.

For more than a year, technicians at ISERST have been developing a simple method of thermally insulating refrigerators with the aim of:

- reducing thermal losses by adding insulation material.
- protecting the appliance from sunshine.

This technique, described in greater detail in annex 9.2, reduces the energy consumption of a refrigerator in the shade by more than 25 %. These significant energy savings lead to very short payback times--usually less than 6 months.

ISERST has carried out two experimental programs of insulating refrigerators: one program took place in private households, and the other was carried out in the hospital and in a number of medical dispensaries.

These programs have permitted the testing of the technique: its feasibility, and consumer acceptance. The results of these tests show that the thermal insulation of refrigerators could have a significant influence on household energy consumption.

5.2.4. Ventilation

Apart from cooling the internal mass of buildings during the cool season, ventilation improves the inside air quality by replenishing the air, and makes the interior space more comfortable.

Given the climate of Djibouti, improving the thermal environment is essential since climatic conditions rarely fall inside the comfort zone established by Givoni /5.1/. Annex 5.2 presents a brief review of bioclimatic principles.

In the service sector, and in the more affluent households, comfort is improved by using air conditioners during the hottest periods of the year.

Other households, for whom the cost of air conditioning is too high, use ceiling-fans for cooling. Fans set the air in motion, cooling the body by facilitating heat loss through convection and the evaporation of perspiration.

In many buildings, if bioclimatic design concepts were to be adopted, the excessive use of ceiling, wall and table fans would be avoided.

Buildings should be designed taking account of the prevailing winds, and should be fitted with air-vents in the walls to encourage the natural flow of air through the interior.

Adequate natural ventilation can significantly reduce the use of electric fans. This is especially true during the coolest months of the year.

5.2.5. Air-conditioning

It is the air conditioning load which accounts for the largest part of electricity consumption. Air conditioners are common in the higher-income households and in the service sector, and are often run throughout the year--even in the cooler season.

The consumption of electricity for air conditioning, which peaks in the summer at around 2 pm and again at midnight, is responsible for the peaks in the overall demand curve, and thus to a large extent defines the installed capacity of EdD.

While it is true that during the summer air conditioning is a necessity if one wishes to be comfortable, the impact of this load on the peak demand for electricity could be lessened by the adoption of a number of techniques such as the thermal insulation of buildings and the use of cold storage systems. These techniques are discussed below.

5.2.5.1. Thermal Insulation of Buildings

Very few of the buildings in Djibouti have any thermal insulation. The absence of insulation results in a marked increase in the consumption of electricity for air conditioning.

In Europe, and particularly in Sweden and in France (after the publication of the regulations cited in reference /5.2/), the use of thermal insulation in buildings clearly reduced the amount of energy used for space heating--a reduction which was discernible at the national level.

Insulation material added to a wall, or forming an integral part of it, makes an efficient thermal barrier that limits the loss of thermal energy. The principle is the same whether one is maintaining an interior space above, or in the case of Djibouti, below the outside temperature. The application of this principle to countries with a high demand for air-conditioning does not involve any particular difficulties /5.3/.

During the last few years, several large buildings in Djibouti have been built with thermal insulation. The building which houses the Technology Section of ISERST is an excellent example of energy efficient building design since it combines the use of thermal insulation with bioclimatic architecture.

The use of thermal insulation in buildings is spreading in Djibouti. New techniques are in evidence: for instance, the application of polyurethane foam on the roof of the Europe building, and the installation of polystyrene panels (glued and protected by a mesh of covered fibre-glass), on the main ISERST building.

As shown in annex 5.3, thermal insulation reduces not only the consumption of electricity used for air conditioning, but also the level of electrical power that a building requires, or 'subscribes' to. The actual reduction in energy consumption and subscribed power depends on the amount of thermal insulation installed in the building.

From an economic point of view, the increase in the cost of the building due to the thermal insulation is recovered within two or three years depending on the technique used and the degree to which air-conditioning is employed.

The installation of thermal insulation in roofs (which are thermal barriers but also excellent solar collectors), under the floor slab (in contact with the warm soil), in windows (using double glazing), and in walls, will not only significantly reduce the peak demand for electricity during the summer months, but will also reduce the total final demand fo. electricity.

Energy efficient building design will be encouraged if all parties in the construction sector understand the benefits of thermal insulation, and if regulations are imposed for new buildings in districts with a high level of air conditioning. The Ministry of Urbanization and Housing, in consultation with ISERST, has drafted regulations to this effect.

It thus appears possible that the use of thermal insulation could, in the short term, flatten the profiles of electricity demand, and of energy consumption related to air conditioning.

5.2.5.2. Cold Storage Systems

Certain western countries, and particularly some states in the United States, confronted with excessive peaks of electrical consumption in summer, have launched ambitious programs of research into the daily storage and release of 'cold'.

This technique aims at producing cold during the hours when electrical consumption is at a minimum. This cold, which is stored as ice or by phase change materials, is then released during the day during the period of peak demand. People who install such devices no longer contribute to the peak electrical demand. The result is a smoother curve of electricity consumption.

Unlike the majority of the measures discussed above, there is no reduction in the consumption of energy with this technique. But there is a much better distribution of the periods of consumption: the peak demand is reduced while the base is broadened.

From the point of view of the electricity company, the interest of such a measure is obvious; but from the consumer's point of view, only the introduction of a tariff with lower charges for non-peak load consumption would enable the additional investment to be recovered.

The success of a cold storage system of cooling is therefore linked to changes in the electricity tariffs. However, such a revision, which would have important consequences for the future capacity of the electrical generating plants in Djibouti, would be difficult to implement given the present accounting and billing procedures of EdD.

It is nonetheless recommended that a study of the costs and benefits of this technique be conducted.

5.2.6. Transport

The transport sect'r is the largest sectoral consumer of energy, accounting for one third of the total demand. The impact of every measure concerning this sector is therefore of particular importance. This is the case, for instance, for measures concerning private vehicles or the buses and mini-buses.

5.2.6.1. Private Vehicles

Carburettor tuning, setting the ignition system, and cleaning the air filter, are all simple measures which help to maintain the fuel consumption of a vehicle close to the maximum values often quoted by the manufacturers.

Unfortunately, these simple maintenance procedures are often neglected, which can lead to a more than 10 % increase in fuel consumption. The wrong tire pressure and useless over-loading are also factors that contribute to excessive fuel consumption.

Since the impact on the level of petroleum fuel imports is significant, it would be advisable to introduce measures aimed at ensuring that the maintenance procedures outlined above are observed.

Other points could also be stressed in a media campaign. For instance, the increase in fuel consumption due to the excessive use of air conditioning; the choice of body color; engines idling during long stops, etc.

5.2.6.2. Buses and Minibuses

The transportation of people, both in Djibouti ville itself and between Djibouti ville and the other districts, is mostly carried out by bus and minibus. Paragraph 1.4.3 discusses in more detail the present situation regarding the public transportation system.

The bus and minibus owners run their vehicles almost continuously every day, trying to maximize the return on their investment.

However, this mode of operation is counter-productive. The number of vehicles operating each day is much greater than that required to service the number of passengers; the poorly maintained vehicles therefore consume more fuel than they would if they were better serviced and maintained.

There are several measures which could reduce the excessive fuel consumption that contributes to the very low profitability of the family transport firms. Among these measures are not only those mentioned in the preceeding sections, but also those concerning route planning, and the operating schedules of buses and minibuses.

Perhaps the most important of these measures concerns the division of the fleet of public transport vehicles into two groups, each group being only allowed to run every other day--apart from peak periods.

However, dividing the fleet of buses and minibuses has consequences which go beyond energy considerations. This proposition is analysed in much greater detail in annex 9.5.

5.2.7. Recapitulatory Table

Table 5.2.1 summarizes the measures that could influence, over the short term or mid term, the evolution of energy demand for a particular economic sector. A reduction in the level of energy consumption is in most cases effected either by improving the efficiency of a system, or by introducing the appropriate technical measures.

An estimate of the possible energy savings which could be achieved is also given for each type of end-use.

Table 5.2.1. Final Energy - Table of Possible Improvements

	Present technology	Improved technique	Potential gain in efficiency
Cooking	fuelwood, 3 stone fire	improved stove (clay, sand)	50 %
Lighting	incandescent	fluorescent, high efficiency lamps	70 %
	mercury vapour	high pressure sodium, low pressure sodium	40 %
Refrigeration		thermal insulation	25 %
Ventilation	ceiling fan	natural ventilation, high and low wall openings	variable
Air conditioning		thermal insulation of buildings	30 %
Transportation	vehicles	regulation of carburettor	10 %
	buses	division of the fleet into groups A and B	30 % approx.

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ANNEX 5.1 THERMAL INSULATION OF REFFRIGERATORS

The excessive electrical consumption of refrigerators and refrigeration systems has led ISERST to study ways in which this energy consumption might be reduced.

The technical solution to this problem needs to satisfy a number of criteria:

- it should be cheap.
- the payback time should be short.
- the technique should be simple and quick.
- the materials required should be locally available.
- the appearance should be acceptable to the user.

Several techniques were tested at ISERST both for thermal performance and ease of application.

The technique which was finally selected consists of 3 steps as shown schematically in Figure A 5.1.1.,namely,

- constructing a wooden frame,
- inserting sheets of thermal insulation such as polystyrene,
- adding a finishing cover of thin plywood or vinyl sheeting.

Tests carried out at ISERST showed that energy savings of more than 25 % are possible for a refrigerator located in an interior space. A refrigerator placed outside in a courtyard showed savings of more than 30 %.

The cost of adding the insulation and the finishing cover varies between 3,000 and 4,000 FD according to the size of the refrigerator. This investment is recovered by reduced electricity bills in about 4 months.

After experimenting with the new technique, ISERST conducted 2 programs in order to test the acceptability of the insulated refrigerators and the feasibility of the method used to install the insulation, and to confirm that the actual savings realised were as projected.

The first program was carried out in the residential sector, while the second was conducted in the service sector-- in local hospitals and dispensaries.

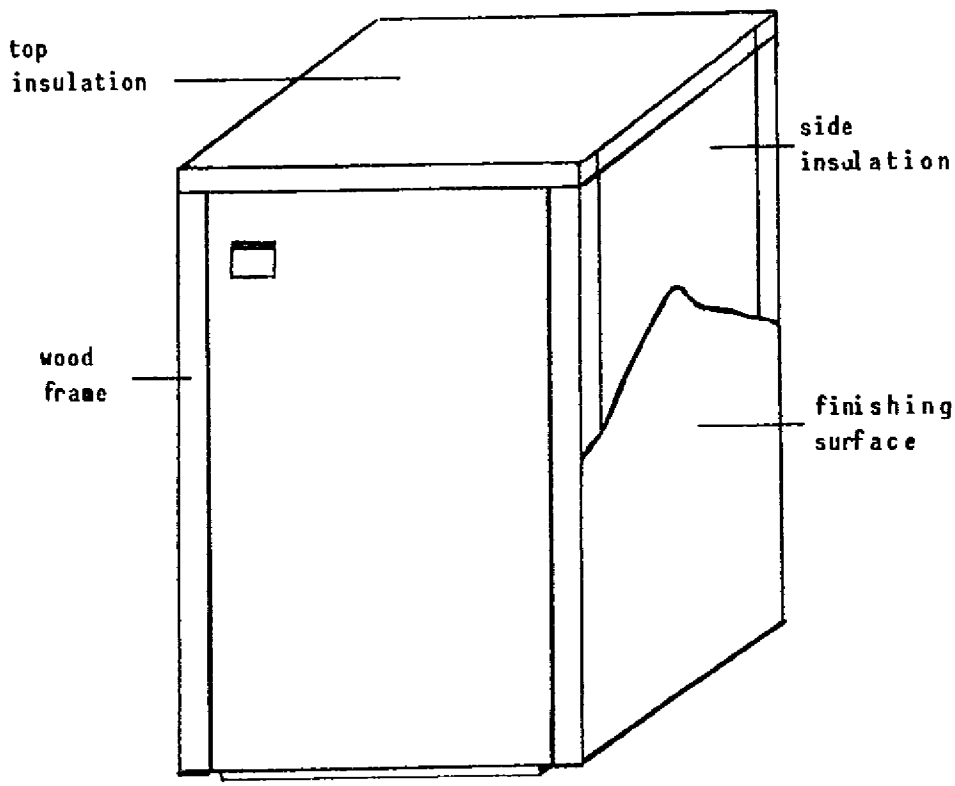


Figure A5.1.1. Refrigerator Insulation

These programs were each carried out on about 100 refrigerators. The results obtained were extremely encouraging --both in terms of the acceptability of the modified refrigerators, and the energy savings which were measured.

A major program aimed at disseminating this technique has been proposed and designed. The program would insulate about 11,000 refrigerators--about half of the refrigerators in Djibouti. This program would reduce the overall national demand for electricity, and would bring significant savings for both the nation and for individual consumers.

ANNEX 5.2 THE CONCEPT OF THERMAL COMFORT

Thermal comfort is a sensation which is very subjective. Each individual has his or her own sense of what constitutes a comfortable environment.

For instance, some people are comfortable in a temperature of 28 °C, while others find 25 °C already stifling.

Numerous scientific studies have tried to determine the factors which play a major role in the sense of comfort. Among these factors are obviously the temperature, but relative humidity, air movement, type of clothing, and the activity of the person all play a part.

Based on these principal parameters, charts such as those by Givoni /5.1/ show schematically the zones of comfort and discomfort for the average person.

Figure A 5.2.1 shows that the zone of comfort, for a situation where there is no movement of air, has an upper limit of 27 °C for a dry climate, and 25 °C for a very humid climate.

The effect of ventilation on comfort is shown schematically in Figure A 5.2.2. The comfort zone is appreciably enlarged. With appropriate ventilation, a person could be comfortable at a temperature of 32 °C.

This concept is an important component of the energy efficient, bioclimatic building designs being promoted in Djibouti. These designs take advantage of the cooler easterly winds which blow for most of the year.

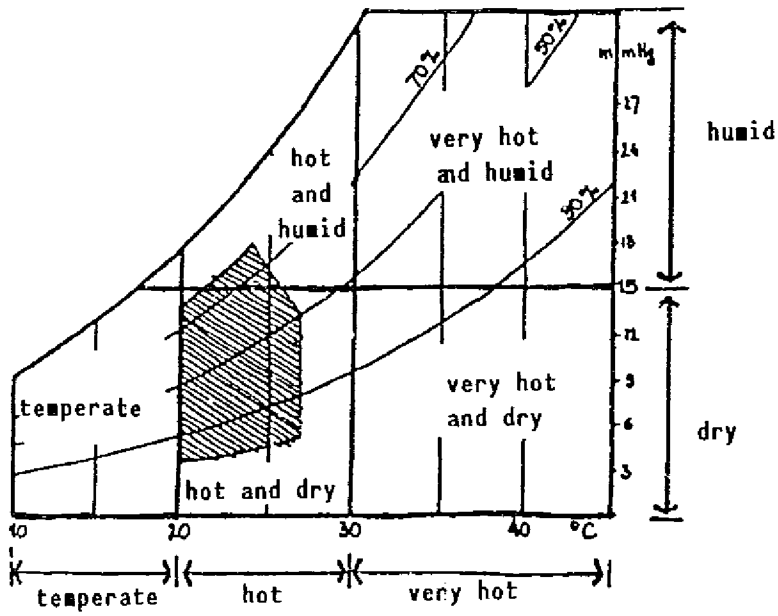


Figure A5.2.1 Zone of Thermal Comfort

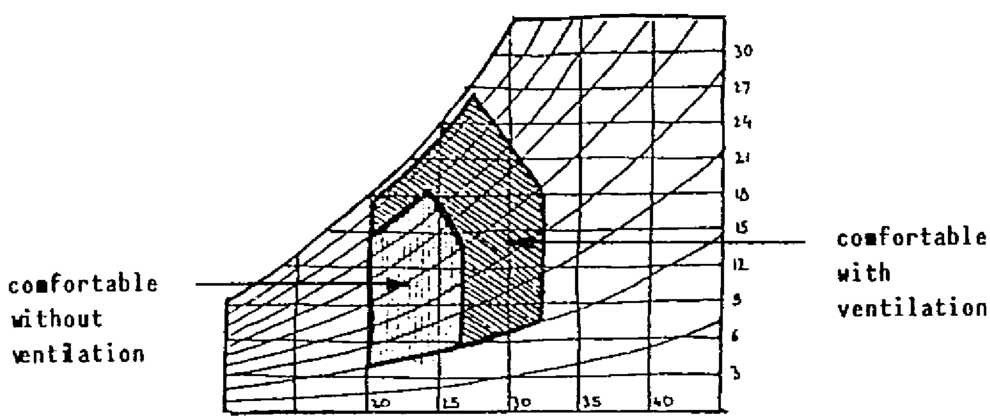


Figure A5.2.2 Effect of ventilation on Comfort

ANNEX 5.3 THE INFLUENCE OF THERMAL INSULATION ON AIR-CONDITIONING LOAD

This annex presents a very simplified analysis of building construction in order to show the importance of thermal insulation on the air conditioning power required to ensure comfort.

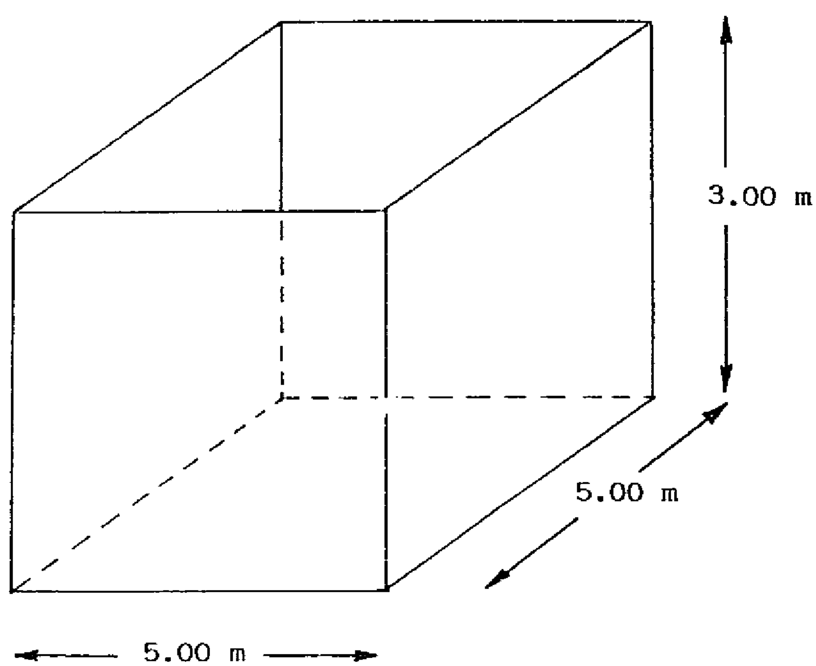
The calculation considers only the thermal losses through the building envelope, and does not take into account other factors which, in a more detailed analysis, would also need to be included.

I) Uninsulated Building

The dimensions of the building are shown in Figure A 5.3.1. The characteristics of the building construction are given in Table A 5.3.2.

The calculation assumes an extreme temperature difference: 25 °C inside the building, 45 °C outside the building.

Figure A 5.3.1 Building Dimensions



Floor surface: 25m2 Volume: 75m3

Table A 5.3.2 Characteristics of the Building Surfaces

	Walls	Floors	Roof
Surface area	60 m2	25 m2	25 m2
Material	20 cm concrete	20 cm concrete	20 cm concrete
K, no insulation	3.01 W/m2.K	1.75 W/m.K	3.44 W/m2.K
K, 4 cm insulation	0.75 W/m2.K	1.15 W/m.K	0.77 W/m2.K
K, 8 cm insulation	0.41 W/m2.K	0.85 W/m.K	0.43 W/m2.K

The rate of thermal energy loss is given by the following expression:

$$P = (k_p \times L_p + K_m \times S_m + K_t \times S_t) \times \Delta T$$

where:

P = air conditioning power, watts

k_p = linear transmission coefficient for the floor, W/m.K

L_p = floor perimeter, m

K_m = surface transmission coefficient or the walls, W/m2.K

S_m = surface area of the walls, m2

K_t = surface transmission coefficient for the roof, W/m2.K

S_t = surface area of the roof, m2

ΔT = temperature difference between the interior and exterior, °C

The air conditioning power required is therefore given by:

$$P = (1.75 \times 20 + 3.01 \times 60 + 3.44 \times 25) \times 20$$

$$P = 6,032 \text{ W}$$

II) Insulated Building

The calculation is the same as that set out above, except that the new values of the transmission coefficients are now used.

In order to show more clearly the influence of thermal insulation, the calculation is performed for 2 thicknesses of polystyrene insulation: 4 cm and 8 cm.

II.1) 4 cm of insulation

$$P = (1.15 \times 20 + 0.74 \times 60 + 0.77 \times 25) \times 20$$

$$P = 1{,}733 \text{ W}$$

II.2) 8 cm of insulation

The calculation is similar:

$$P = (0.85 \times 20 + 0.41 \times 60 + 0.43 \times 25) \times 20$$

$$P = 1{,}047 \text{ W}$$

III) Comparison

This quick calculation clearly shows the importance of thermal insulation for buildings which are air conditioned. Without insulation, over 6 kW of power is required. This figure drops to 1.7 kW for the building with 4 cm of insulation, and falls again to just over 1 kW for the building with 8 cm of insulation.

Thus, in this simple example, the addition of 8 cm of thermal insulation reduces the level of thermal power required by a factor of 6.

Table A 5.3.3 Results of the Calculation

	Power required
Without insulation	6,032 W
4 cm of insulation	1,733 W
8 cm of insulation	1,047 W

CHAPTER 6

HYPOTHESES AND SCENARIOS CONCERNING THE SOCIAL AND ECONOMIC DEVELOPMENT OF DJIBOUTI

The demands of economic growth as well as improvements in the standard of living for Djiboutians will lead over the mid and long term to higher levels of energy consumption. However, simply knowing that such a phenomenon will take place is not sufficient information for the development of a long term energy plan. It is necessary first of all to determine the structure and level of energy supply and demand which will occur given different development scenarios.

This approach leads first to an analysis of the structure of energy demand as a function of socio-economic needs. This is followed by an evaluation of the level to which this demand might rise for each sector of the economy. Finally, the impact of energy conservation and demand management measures must be taken into account since a more rational or more efficient use of energy may reduce the amount of energy required for certain tasks, or may change the structure of energy use at the same level of consumption.

The development of a coherent energy policy can only be carried out with a long term perspective. In fact, one of the characteristics of the energy sector is its rigidity over the short term. This inflexibility manifests itself at two levels:

a) On the demand side, at the level of consumer behaviour, individual changes in the way in which energy is used do not have an immediately significant impact on the overall level of energy demand.

b) On the supply side, the long periods required to amortize energy investments require that the projection of future demand is carried out over a planning period which is consistent with the time required to implement energy projects and with their economic life times.

In energy planning it is always necessary to take account of the difficulties arising from the time required to carry out energy policy. The actions of the Government agencies and authorities, who are the ones presented with the results and conclusions of the simulations, are too often based on short term perspectives and exigencies. It is essential that the importance of long term energy planning is understood by Government planners and decision-makers.

As a generalisation, the issue raised above is that of the link between projection and decision. Decisions relating to energy policy and planning are taken by Government agencies charged with the management of the energy sector. But these decisions can only be based on a range of projections. The forecasts and projections must be transparent, with all assumptions clearly stated, so that decision-makers can effectively plan for the future.

6.1 METHODOLOGY

The development of the different scenarios follows the three steps set out below.

a) First of all, a qualitative description of the political, economic and social evolution of the economic system is developed. Such a description serves as a reference against which the coherence and the plausibility of the different numerical hypotheses may be judged.

b) This is followed by a more detailed identification of the changes that the general description outlined above will logically bring about in the different economic sectors, in the way of life, in the modes of transport, in the technologies using energy, etc.

c) Finally, the scenarios are translated in terms of quantitative hypotheses for all the indices which define a scenario, beginning with the socio-economic sub-scenario, and ending with the energy sub-scenario. This step requires a systematic analysis and a modeling of the various sub-sectors in such a way that the overall scenario may be coherently structured.

The scenarios modeled in this study should be considered exploratory scenarios. They rest on the assumption that the evolution of the socio-economic system will tend to follow the same pattern of development as that seen over the last decade. The simulation is taken up to the year 2000--a period long enough to determine the effects of structural changes on energy demand.

A longer perspective would have called for a much greater effort, particularly in view of the lack of detailed studies on the long term development of Djibouti. The reference year for the simulation is 1985; the years 1990 and 1995 mark the intermediate points between the reference year and the year 2000.

6.2 THE BASIC STRUCTURE OF THE ECONOMY

The economic development of Djibouti is tied to the following factors :

a) In the primary sector:

- the average rate of increase of the GDP during the last five years has been about 2.5% per year -- the GDP per capita has therefore been declining.
- the primary sector contributed in 1985 to only 4.5% of the GDP, and the degree of self-sufficiency of the country in food supply remains very limited.
- with regard to water supply, there has been significant progress. However, in the rural areas the consumption of water is below that considered the minimum advisable for such a climate. The evaluation and exploitation of subsurface aquifers is a necessity. However, the progressive salinization of many wells poses a serious problem.
- vegetable production has markedly increased--national production moving from 50 tonnes in 1979 to close to 1300 tonnes in 1986. However, there are constraints which limit the range of agricultural products which can be produced at a competitive price.
- livestock raising has created problems in many regions due to over grazing; the desertification of some areas is apparent.
- with respect to fishing, efforts to increase production are hindered by the demand for fish which, although increasing, remains relatively low.

b) With regard to industry, its part of economic activity remains very small. In 1984 the industrial sector accounted for only 8 % of GDP. However, a number of industrial and artisanal projects are either under study or are planned for the near future.

Industrial development policy is aimed at import substitution. With demand so weak, however, the national market remains underdeveloped. Given the economic situation over the mid term, industrial production is unlikely to grow to the point where economies of scale might permit it to compete internationally.

c) The development of an effective infrastructure must still be regarded as unattained. The road transport system consists largely of tracks or unsurfaced roads which are travelled with difficulty and in some cases are impracticable for heavy trucks. However, it should be noted that the Route de l'Unité between Djibouti ville and Tadjourah will encourage the transport of goods by road.

d) In the energy sector, the cost of imported energy amounts to 10 % of Djibouti's GDP and 32 % of net imports.

To lessen the weight of imported petroleum on the balance of payments, the Government has implemented an energy policy which focuses on the exploitation of geothermal resources, continued support for the use of solar and wind energy, and the introduction and dissemination of energy conservation measures.

The traditional fuels, notably fuelwood, occupy a significant place in the national energy balance -- about 16% of final energy demand. However, the supply of fuelwood is diminishing in a number of regions as a result of drought and overgrazing, and a part of the population, particularly the rural population, faces problems with the supply of fuelwood.

6.3 THE SOCIO-ECONOMIC AND ENERGY SCENARIOS

In order to better visualise the impact on energy demand of the two scenarios modeled by MEDEE-S for Djibouti, it was decided to choose scenarios which employed quite different socio-economic and technical indices.

The first scenario, referred to as the reference scenario, assumes that the economy continues to grow at the present rate, with no significant changes taking place either in the structure of the GDP or in the pattern of household energy consumption.

The second scenario, referred to as the growth scenario, assumes that the growth of the economy will be more rapid: increasing at an average rate of 5 % per annum until the year 2000.

The growth scenario models the principal components of the Government's plan for Economic Development (Programme de Redressement Economique) for the period 1986-1990. The objectives of the plan may be summarised as follows:

a) A vigorous effort in agricultural development brings a reduction in the level of food imports, an easing of the trade deficit, an improvement in living standards in the rural areas, and a more balanced economy.

Actions to increase the production of vegetables, and to enlarge the cultivated areas under irrigation will be supported by the setting up of a development program in agricultural systems. This step takes into consideration agricultural policy, institutional constraints, and the problems posed by irrigation and the protection of the physical resources which could affect the efficient operation of the production system.

The program for agricultural development is estimated to generate an average rate of growth of about 9 % per year, which would give agriculture 8.5 % of the GDP by the year 2000.

b) In the same manner as for the primary sector, the scenario assumes strong growth by the industrial sector. Industrial development policy leads to an increase in the value added nationally, a reduction in the commercial trade balance, a reduction in the level of unemployment, and the development of a strong industrial base in the country.

In the short term, the hypotheses concerning industrial growth assume both the growth in the size of the existing industries, and the implementation of several projects already under consideration such as a tannery, brick making plant, cement works etc.

In the mid-term and over the long term, given the limited size of the national market, industrial development will be influenced to a large degree by the economic development of neighbouring countries, and by measures to encourage the private sector, both local and foreign, to contribute to the funding of industrial development projects.

Based on the progress outlined above, the scenario leads to a rate of sectoral growth of about 8 % per annum. This rate of increase shifts the part of industry in the GDP from 8 % in 1985 to 13 % in 2000.

c) Concerning the road system, the scenario assumes the implementation of a program to improve and extend the road network. The improvement of the national road system will support efforts to open up the interior areas , and to develop commercial activity in those regions where growth in the primary sector is impeded by the lack of effective transportation.

d) The energy sector is one of the keys to the development of Djibouti. It is assumed that a vigorous energy policy is pursued based on the development of geothermal energy for electrical power generation, on the continued exploitation of solar and wind energy resources, and on the implementation of comprehensive measures which will ensure that energy is used more efficiently.

It is projected that the quantity of petroleum imported for the production of electricity will clearly diminish over the next 15 years. The trade balance improves commensurately.

Concerning wind and solar energy, although it is expected that they will play a larger role in the future for industrial water heating, water pumping in the rural areas, etc., their contribution will remain limited in comparison with supplies of conventional energy.

e) With regard to interfuel substitution, this aspect is modeled by setting the rate of penetration of the different forms of energy both by region and by end-use.

These hypotheses involve principally the penetration of electricity. The scenario assumes a strong penetration by electricity in the industrial sector and in the residential sector. Similarly, it is assumed that kerosene replaces fuelwood in the low-income urban households and in the rural households, and that LPG replaces kerosene in other urban households.

f) In the area of transportation the growth scenario is characterised as follows :

- a significant improvement in the road transport system leads to a clear increase in public transport and in road freight transport.
- strong economic growth is assumed to generate higher real incomes, and consequently an increased number of private vehicles.
- the tendency towards Diesel-engine vehicles is assumed to continue, thus leading to an overall improvement in the energy efficiency of the transportation sector.

g) Turning now to the demographic situation, the growth scenario assumes the following :

- a strong growth in the urban population leading to 75% urbanization by the year 2000.
- a reduction in average family size, particularly of the urban families.
- a continuation of the tendency of the nomadic population towards sedentariness.
- significant changes in the income-level structure of households.
- a significant increase in the number of urban and rural households with electricity supply.

The basic hypotheses of the 2 scenarios, set out in numerical form, are shown in Table 6.3.1.

Table 6.3.1 Indicators Defining the Scenarios

INDICATOR	1985	2000 growth scenario	2000 reference scenario
1. DEMOGRAPHY			
- Population (thousands)	430.0	670.0	670.0
- urbanization	58 %	75 %	65 %
- average urban household size	7.5	6.0	6.5
- average rural household size	8.2	7.0	7.2
2. STRUCTURE OF URBAN HOUSEHOLDS (%)			
- low income	71.8	71.0	75.3
- middle income	16.5	22.1	16.5
- upper income	5.2	4.5	5.2
- expatriates	6.5	2.4	3.0
3. GROSS DOMESTIC PRODUCT (GDP) (billion FD)	60.2	125.2	108.5
4. STRUCTURE OF GDP (%)			
- agriculture	4.5	8.5	7.0
- construction	7.5	9.0	8.0
- services	76.6	63.5	71.8
- energy	3.2	6.0	3.2
- industry	8.2	13.0	10.0
5. HOUSEHOLDS WITH ELECTRICITY (%)			
5.1. Urban			
- low income	54.0	93.0	76.0
- remainder	100.0	100.0	100.0
5.2. Rural			
- rural centres	15.0	44.2	34.2
6. TRANSPORT			
- number of private vehicles	11,622	16,370	15,600
- number of public vehicles	521	1,208	938
- number of freight vehicles	430	962	774

CHAPTER 7

THE MEDEE-S MODEL: A BRIEF DESCRIPTION

7.1. THE MEDEE-S APPROACH TO FORECASTING ENERGY DEMAND

7.1.1. Selection of a Methodology for Forecasting Energy Demand in Djibouti

The selection of a methodology for forecasting energy demand for the case of Djibouti is based on three considerations:

a) First, a fairly simple method of analysis is needed in order to estimate the country's energy consumption in a general manner, to identify the range of possible evolutionary paths, and to assess the risks involved with the energy policies that are under consideration.

The methodology should permit the demand for energy to be studied at the sectoral level, at the level of energy use and the different forms of energy, while taking into account the socio-economic characteristics of Djibouti.

b) Second, the methodology should be capable of being adapted to the existing energy database, and should allow the use of all the available information and statistics.

For Djibouti, the knowledge of final energy consumption is generally insufficient, and is virtually non-existent for certain sectors and uses. Therefore, the methodology should also provide a logical structure for the identification of additional information and for the acquisition of data. The forecasting exercise should be considered as a means of developing, improving and testing the coherence of information and data on energy consumption and final demand.

c) Third, the method of analysis should play a pedagogical role since energy planning in Djibouti is a recent development--now being jointly undertaken by ISERST and the Energy Service.

Training a professional team responsible for national energy planning requires an analytical tool which enables one to clearly see the structure of energy demand, its fundamental mechanisms, and the major issues to which energy policies must be directed in order to influence and to plan for the evolution of future energy demand.

These considerations have led to the selection of the MEDEE-S model. This choice is supported by the successful application of the model in several countries having very different characteristics--area, population, level of development, and infrastructure.

7.1.2. Classical Forecasting Models

Traditionally, energy demand forecasts over the medium and long term are based on aggregate data such as gross domestic product (GDP), population, and energy prices.

Energy requirements are deduced from these indicators using econometric models of varying complexity.

The classical methods of forecasting take a very limited viewpoint. They assume static relationships based on those which held in the past, and use deterministic models to predict the future. These methods suffer from a number of limitations:

- The methods only take into account a limited number of independent variables, and assume that all the others remain unchanged. This method of analysis becomes dangerous when overall energy demand needs to be estimated in a context where technology is continually changing.

- The methods are inflexible in that they assume static relationships between key variables which can in no way be modified following any significant change. Numerous errors in forecasting are due to this rigidity which is clearly illusory in a world which is changing more and more rapidly.

- The classical forecasting methods use the patterns observed in the past to predict those of the future. Even if the variables change, they still retain their fixed relationships. The deterministic approach on which this method is based cannot be considered viable when there is no means of proving that the modes of evolution witnessed in the past will be repeated in the future.

Although econometric models are very useful in certain applications, the limitations of these methods of forecasting, briefly outlined above, show that econometric models have great difficulty in taking into account the evolution of certain relationships, or in integrating new fundamental relationships for forecasting over the medium and long term.

As a result, the validity of these models is limited to a forecasting period during which the evolution of new parametric relationships plays only a minor role.

The drawbacks of traditional forecasting techniques have led to the study of techno-economic approaches such as MEDEE-S, capable of giving sufficient information on real energy dynamics in developing countries, and of evaluating the range of possible options available for effective energy demand management. The objectives of the MEDEE-S model can be summarised as follows:

- to identify the degrees of freedom present in the link between energy and gross domestic product, while taking into account the impact on energy demand of certain choices in the transport sector, the residential sector, and the production sector.

- to distinguish between the energy demand of the modern sector--the set of activities, regions, and social classes which approach a "developed" country mode of consumption--and that of the "traditional" sector in which the simple satisfaction of basic needs plays a dominant role.

- to assess the potential of each type of energy by carefully evaluating the possible combinations of supply and demand in such a way that the possibilities for developing local energy sources, either renewable or fossil, can be evaluated.

- to clearly show the relationship between the rate of penetration of conventional energy in the rural sector, and in certain social groups of the urban sector, and the rate of growth of their demand for energy.

7.1.3. Description of the Model

The MEDEE-S model is characterised by a detailed disaggregation of energy demand. The total demand is broken down into several homogeneous basic demands, the evolution of which is induced by the socio-economic and technological factors which determine energy demand.

In the model, the evolution of the levels of satisfaction of individuals needs, the levels of economic activity, the distribution of the population into different classes, technical changes, or substitutions between types of energy, are specified exogenously for each scenario.

Since the evolution of the determinants of energy demand is defined exogeneously, one should not strictly speak of a 'model', but rather of a tool for studying the flow of energy towards its point of final use. In fact, the model encompasses a group of automated procedures which, based on a series of multiplications and additions, are employed to calculate the final energy demand.

The MEDEE-S model is a very flexible instrument the structure of which can be adapted both to the particular application at hand, and to the available data.

The principal characteristics of the model include the following aspects:

- mode of disaggregation
- choice of computational procedure
- use of additional procedures
- consideration of specific fuels
- final energy - useful energy
- the model variables.

7.1.3.1. Mode of Disaggregation

One of the first steps in the MEDEE-S approach consists of breaking down the total energy demand of the country under consideration into 'modular' demands at a level of detail compatible with the degree of precision required.

The way in which the energy consumptions are disaggregated (the structure of the model in fact), does not correspond to a fixed theoretical scheme, but can be redesigned for each particular application.

The model consists of 5 basic sub-models, to which is added the macro-economic sub-model which calculates the level of activity of the productive economic sectors.

For each sector, the model consists of a basic procedure, used in all cases, and additional procedures which can be added in order to study in greater detail a particular sector or use. These additional procedures, which are specified using command variables, are used to highlight important sectors and end-uses.

Table 7.1.1 summarises the different sectors and end-uses employed by the model.

Table 7.1.1. Structure of the MEDEE-S Model of Djibouti

Sub model	BASIC PROCEDURES level of disaggregation	energy uses	Supplementary Procedures
INDUSTRY	sub sectors or components	- liquid fuels - thermal energy - specific electricity	- steel industry - major energy consumers
RESIDENTIAL	geographic region urban - rural social -economic class	- cooking and other thermal uses - lighting and specific electricity	- electric appliances
SERVICE	sub-sectors or components	- specific electricity - other thermal uses	- public lighting - water pumping - other uses (military)
TRANSPORT	passenger transport freight transport international transport		- urban transport
AGRICULTURE	aggregate analysis analysis by product	- liquid fuels - thermal uses - specific electricity	

The Household Sub-Model

The household sub-model covers two basic end-uses: cooking and lighting. The 'electric appliance' procedure can also be added to this group in order to analyse the energy demand in greater detail. It should be noted that if only the basic sub-model is used, the electric appliance end-use is included in lighting.

To disaggregate the residential sector, and to define it more precisely, the population can be subdivided not only into the traditional urban family - rural family groups, but also into socio-economic classes. These can be defined independently for the urban and rural areas.

Similarly, in order to take into account regional disparities caused by differences in the access to commercial forms of energy, or by climatic conditions, it is possible to model several large regions.

The Industrial Sub-Model

This sub-model consists of a basic version and two supplementary procedures: the steel industry, and other industries which are major energy consumers. In the first case, the energy demand is linked to the added value of the industrial sector; in the second case, the demand is linked to the volume of production physically produced and to the production processes employed.

The basic module allows the sector to be grouped into a few large categories or industrial sub-sectors, thus permitting the structure of industrial development to be accurately represented.

Three main uses of energy can be distinguished: specific electrical uses, mechanical uses and thermal uses. This allows the possibility of inter-fuel substitutions to be analysed, as well as the development of new energy sources and new technologies.

The projection of energy consumption is deduced from each component of the evolution of the value added, and from the evolution of energy content (final energy consumption per unit of added value) for the large users (electricity, fuels and thermal uses).

The Service Sub-Model

The tertiary or service sub-model consists of a basic sub-model in which energy demand is related to employment (specific energy consumption per worker), and is sub-divided into two groups: specific electrical usage (actual use of electricity), and thermal usage (actual fuel use).

The model allows a division in terms of activity--the number of sub-sectors depending on the contribution of the energy consumption of each component to the total consumption of the sector. Ar rt from the utilisation of the basic module, two supplementary procedures can be used to calculate the electricity demand for street lighting and the pumping of water.

The Transportation Sub-Model

This sub-model consists of a basic sub-model in which three types of transport are defined: the domestic transport of personnel, the domestic transport of goods, and international sea and air transport. All of these modes of transport are characterised by their capacity (number of vehicles in the case of road transport, and the number of seats offered in the case of rail and air transport), by their level of utilisation, and, finally, by the type of energy or fuel used.

In the case of personnel transport, 3 categories of transport are defined : domestic air transport, where the traffic is dependent on the economic activity of the country; individual motor vehicles, which is dependent on personal income; and finally public transport, where the traffic depends largely on supply.

The transport of goods is linked to the sectors that generate the need for transport: agriculture and industry. The road vehicle fleet is separated into different homogeneous categories, and traffic is estimated from the number of vehicles and their use, their specific fuel consumption, and the fuels used.

An additional procedure can provide a detailed analysis of urban public transport. A number of modeling approaches are possible depending on the amount of information available concerning the number of people travelling by each mode of transport.

The Agricultural Sub-Model

Due to the minor contribution of this sector to the total energy consumption, an approximate disaggregation is generally sufficient in order to analyse the evolution of the sectoral energy demand. The principal uses of energy that should be considered are mechanical energy for irrigation and for traction, the fuel used by fishing boats, and the energy used for conserving and drying agricultural produce.

This sub-model permits a choice between two methods of calculation, allowing the procedure to be adapted to the available data. One method looks at agricultural production in terms of added value, and differentiates between three types of energy: liquid fuels, electricity, and thermal energy.

The second method relates energy consumption to the equipment and techniques used. Four types of energy demand are considered: fuel for mechanical power, fuel for fishing boats, fuel used for irrigation, and fuels used to generate heat.

7.1.3.2. Choice of Computational Procedure

MEDEE-S offers the possibility of choosing different computational procedures for certain variables depending on the precision of the data, and the flexibility required in the projection of certain variables.

In the case of the industrial sector, for example, in order to estimate the penetration of certain forms of energy for the generation of heat, two alternative computational procedures can be employed. The first method is based on an evaluation of the temperature of the thermal energy (low, medium and high temperature); the second method estimates the penetration for each sub-sector without taking account of the thermal characteristics of the application.

Similarly, in the transport sector, the disaggregation of freight transport can be determined either by means of the contribution of each mode of transport to the overall traffic, or by determining rail and maritime traffic, the difference between the two giving retail sales. In the same way, the projection of the number of vehicle-km can be calculated by two alternative methods : either by considering the growth in the demand as a function of the evolution of supply over the long term, or by considering the demand as dependent on supply.

7.1.3.3 Useful and Final Energy

The demand for energy is derived from the calculation of final energy--the level at which the basic data of the model are defined.

The results of the simulations are also presented in terms of final energy. However, the MEDEE-S approach works in terms of useful energy for applications where different types of energy can be substituted for each other--the generation of heat for instance. For these uses, the same social needs, or the same level of economic activity (in other words, the same need for useful energy), can lead to different final energy demands depending on the type of energy used.

Annex 7.1 shows the list of command variables, and the values which correspond to the application of the model to the case of Djibouti.

Constants

The application of the model is based on a detailed representation of energy consumption for a reference or base year. The constants represent the consumption data for the base year.

Scenario Variables

Another particularity of the model is that it has a limited number of scenario variables--the number depending on the level of disaggregation of the model. This is due to the fact that only those exogenous variables which remain relatively independent over the long term are retained as scenario variables.

The scenario variables represent:

- evolution indices (which have a value of 1 for the reference year),
- elasticity coefficients, relating the evolution indices of two variables, and defining the difference in the rates of growth of the two variables,
- structural variables.

Exogenous Variables

Exogenous variables are variables whose evolution is independent of the scenario being modelled.

7.2. THE APPLICATION OF MEDEE-S IN THE CASE OF DJIBOUTI

7.2.1. Background and Context

The economy of Djibouti has certain characteristics which have to be taken into account in order to clearly define the context within which energy demand will be analysed.

First, concerning the statistics from DINAS on energy consumption (principally hydrocarbons), an initial distinction is made between two categories: the domestic market and total consumption.

The first category represents the sales of liquid fuels for domestic consumption, i.e. inside the country. The total consumption includes energy re-exported in the form of fuels for foreign shipping and air transport. Obviously, this latter consumption should not be included in the energy demand imposed by the Djiboutian socio-economic system.

Nevertheless, in the present study, this consumption has been analysed separately for two reasons: firstly, the airport and the port activities represent an important part of the service sector, which alone accounts for about 75 % of the GDP of the country. Secondly, when analysing the long term growth of the energy supply system, it is essential to study the possibility of future energy exports.

With respect to the domestic market, 3 principal components should be distinguished:

1. The consumption of energy by EdD for the generation of electricity. This consumption is an intermediate consumption. It depends on the demand for electricity, the development of the country's energy resources such as solar energy and geothermal energy, and the possibility of interconnection with neighbouring countries.

Consequently, the consumption of energy for the generation of electricity is not a major concern of the model. It should be analysed in the context of an overall optimization of the energy system.

2. The consumption of energy by the French Army is linked to agreements with the French government. Nevertheless, this consumption is considered as exogenous (in the service sector) in order to establish the energy balances for each of the intermediate observation years specified in the model.

3. The final consumption of energy--the rest of the domestic energy consumption--represents the energy needs of the socio-economic system in Djibouti, where this is defined as all economic and social activities which take place inside the borders of the country.

7.2.2. Adaptation of the Model to the Case of Djibouti

7.2.2.1. Modeling the Residential Sector

In order to be able to model the structure of households coherently, and thus to be able to study homogeneous sub-sections of the population in the sense of life-style and level of consumption, the population has been divided into several categories, based on the following criteria :

a) Disaggregation by Area: Taking into account the importance of Djibouti ville as a centre of population, it is essential to distinguish those families living in the town (the urban population) from the remaining families (the rural population). This division allows disparities due to differences of access to the 'commercial' forms of energy (electricity, petroleum fuels) to be analysed, and facilitates the study of the substitution of commercial energy for the traditional forms of energy such as wood.

b) Population Density : Given the importance of the nomad, refugee, and homeless population within the total population of the secondary towns, a further division must be considered in order to be able to capture more clearly the impact of the evolution of the population structure on energy demand.

The population outside of Djibouti ville has therefore been divided into two groups: the population centres, i.e. the population in the District centres and the secondary towns, and the more widely spread rural population including the nomads, the refugees, and the homeless.

c) Socio-economic Disaggregation: In order to take household categories with similar life styles, and therefore similar levels of energy demand, into account, the population has been divided into household categories according to their use of particular electrical appliances. In the urban sector (Djibouti ville) the criterion adopted for this classification is the number of air conditioners per household. The household categories are therefore defined as follows:

- low income households (no air conditioners).
- middle income households (1 air conditioner only).
- higher income households (several air conditioners).

To these categories are added the expatriate households and the collective groups such as the military bases, hospitals, etc.

The energy consumption of the collective groups is included in the service sector. For the rest of the population, i.e. the rural population, the socio-economic disaggregation outlined above is not employed.

d) Energy Uses : Two principal types of energy usage can be distinguished: energy uses considered to be "substitutable", for which substitution by other types of energy may be possible, and "non-substitutable" energy uses which require a specific form of energy. The substitutable energy uses concern primarily cooking and lighting.

The consumption of energy for cooking is determined for each household and area, both for the urban population and the rural population. The degree of satisfaction of energy needs is characterised by a unit consumption (per household) expressed in energy terms, and is defined as a scenario variable for wood (traditional energy) and for LPG, which is considered a strategic fuel in the model. The separation of the energy used for cooking according to the type of energy employed is based on the present structure.

For lighting, the consumption of electricity or kerosene is expressed in terms of final energy. For the case of electricity, the calculation of the number of households with electricity is based on the number of households connected each year, both for the urban and rural populations. These numbers depend on the policy of electrification being followed in the country. The disaggregation of households with electricity by socio-economic class and area follows the actual structure at the beginning of the period under consideration.

Among the non-substitutable energy uses is electricity for electrical appliances, and charcoal used for certain social and religious occasions. For the former, the electricity consumption is calculated for each type of equipment (ventilation, air conditioning, refrigeration, etc.), based on the number of households using the appliance and the annual consumption of each appliance, which is specified for the reference year and then modified by the appropriate evolution index.

7.2.2.2. Disaggregation of the Service Sector

The service sector accounts for a major part of GDP (77 % in 1984), and a significant fraction of final energy demand (18 % in 1985). A relatively detailed disaggregation of this sector is therefore essential if its long term evolution, and its impact on future energy demand, is to be accurately modelled.

In the MEDEE-S model of Djibouti, service activities have been grouped into three sub-sectors :

- Administration and public services,
- Commerce, banks, and insurance companies,
- Hotels, bars and restaurants.

For these three sub-sectors, two types of energy have been taken into account : specific electricity and liquid fuels, which correspond to thermal usage and fuel usage.

In addition to the sub-sectors described above, two other energy uses have been considered: public lighting and water pumping. In order to model the energy demand of water pumping, a sub-model has been added to the original version of MEDEE-S.

To establish the energy balances for each of the intermediate observation years in the simulation, the consumption of the French Army has been included in this sector.

7.2.2.3. The Transportation System

As with the other sectors, the context in which the energy needs of the transport system are created and met has to be identified. The transport system is divided into two principal categories as specified in the MEDEE-S model: the transport of people, and the transport of goods and freight. For each category, several modes of transportation are identified.

For rail and maritime transport, it is not always easy to differentiate between the transport of people and goods, since each of these means of transport carries both people and goods at the same time.

However, the distinction has been retained in order to disassociate the long term evolution of goods traffic and passenger transportation since the dynamics of each mode of transport are quite different.

The separation also allows the possibilities for interfuel substitution, or for the substitution of one mode of transport for another, to be analysed more closely.

7.2.2.4. Agriculture and Industry

These two sectors together represent only 6 % of final energy consumption. Nevertheless, the various development and assistance programs for agriculture and industry, as well as the projects currently envisaged in these areas, suggest that the consumption of energy could strongly increase in the future. As a first approach, the agricultural and industrial sectors are analysed as an aggregate unit.

7.3. SOURCES OF INFORMATION

The step from definitions and concepts to information and numerical data is one of the main obstacles facing the analyst when applying techno-economic models for the forecasting of a country's energy demand.

The search for basic information on the energy situation for the reference year is often impeded by both the multiplicity of data provided by numerous studies or various statistical annuals, and a lack of specific information on energy use, i.e. the structure of energy consumption at the point of final use.

One of the advantages of the MEDEE-S model is its flexibility in modeling each sector. This means that the method can be adapted to the available data and information concerning the energy situation.

For Djibouti, the application of MEDEE-S has led to a number of actions which have improved the energy data base, such as:

- identifying the data requirements and highlighting the weaknesses or the lack of information for certain areas or usages.

- providing a coherent system for data acquisition, and identifying the pertinent indices which need to be obtained.

- testing the coherence of the existing data and estimates.

- estimating more precisely data which was unknown or very approximate by successive iterations of the model.

With regard to information which is both systematic and consistent, the statistical annuals of Djibouti issued by DINAS , and the annual reports of EdD have provided a significant part of the data base.

The statistical annual published by DINAS provided demographic and macro-economic data on:

- production activity
- employment
- transport: number of private and freight vehicles, traffic for each mode of transport.
- total imports, exports, and sales of hydrocarbon fuels.
- the national energy balance.

The following stastistics can be found in the EdD report :

- electricity generation and consumption disaggregated by subscribed power,

- the number of customers.

Among the non-systematic information which is available, the survey of household consumption in Djibouti ville carried out by DINAS should be mentioned. This survey looked at samples of the urban population, divided into different zones, and provided information on the standard of living, the number and type of electrical appliances, and the fuels used for cooking.

A number of other recent reports on a variety of subjects also provided a certain amount of data and information on the energy situation in Djibouti.

For the most part, data on the consumption of the different types of energy, on the consumption by sector, and on the consumption differentiated by end-use, were not available. These data have therefore been estimated from various sources of information, using certain assumptions regarding coefficients of energy consumption, and the level of productive activity in the different sectors.

The coherence of the estimated data was checked against several sources of information, and refined by successive iterations of the model.

ANNEX 7.1. COMMAND VARIABLES USED IN THE MEDEE-S MODEL

NAME AND DEFINITION	VALUE	REMARKS
GLOBAL VARIABLES		
Region: country name	Djibouti	
Number of observation periods	4	
Periods	1985 1990 1995 2000	
Unit of calculation	TPE	tonne of petroleum equivalent
Number of sectors analysed	5	
Sectors studied	1	Industry
	1	Residential
	1	Service
	1	Transportation
	1	Agriculture
		If sector (i) = 0, the sector is ignored; if sector (i) = 1 the sector is modelled.
Number of sub-models	1	All industries are grouped in 1 sector

C H A P T E R 8

THE EVOLUTION OF ENERGY DEMAND AND SUPPLY

As discussed in Chapter 6, the MEDEE-S model has been used to study two quite distinct scenarios, the basic parameters of which are set out in Table 6.3.1. The results of these simulations are presented in the paragraphs which follow.

8.1. THE EVOLUTION OF ENERGY DEMAND

8.1.1. The Reference Scenario

This scenario assumes that the social and economic development of Djibouti will continue at the same pace as that seen in the last few years. The GDP is assumed to increase at a rate of 4 % per annum, a rate a little above the average rate of increase over the last 5 years which was 2.5 %.

The structure of the GDP changes only marginally, as a result of a slight increase in the contribution of industry and agriculture.

The results of this simulation by the MEDEE-S model are presented in Tables 8.1.1 and 8.1.2.

According to this scenario, which might be termed "Business as Usual", overall energy demand increases by 63 % during the period 1985-2000. The demand for electricity increases by 69 %, petroleum products by 67 %, and biomass by 42 %.

Disaggregating the demand for biomass, one finds that the demand for charcoal is estimated to double, while the final demand for fuelwood increases by only 37 %. However, the manufacture of charcoal imposes its own demand on wood, and the demand for wood as primary energy increases by 45 % to about 19,100 TPE by the year 2000. These estimates emphasize the need to study the forest resource base in Djibouti, and to evaluate the extent of deforestation and desertification.

The demand for kerosene also increases quite sharply --almost doubling during the period.

By sector, this scenario shows a very strong increase in energy demand by industry and construction which increases by 120 % during the period.

It should also be noted that, by the year 2000, the residential sector takes over from the transportation sector as the largest energy consuming sector.

Table 8.1.1 Reference Scenario - Energy Demand, TPE

	1985 (1)	1990	1995	2000
LPG	623	752	857	990
Kerosene	10096	12752	15786	19739
Gasoline	10613	11137	11738	12223
Diesel fuel	22425	27015	32689	39325
Jet fuel	4506	5537	6737	8196
Sub total	48263	57193	67757	80473
Electricity	12018	14113	16781	20263
Wood	10175	11724	12833	13908
Charcoal	842	1094	1346	1691
Renewable energy	-	-	-	-
TOTAL	71298	84124	98717	116335

1. Energy balance

Table 8.1.2 Reference Scenario - Demand by Sector, TPE

Sector	1985 (1)	1990	1995	2000
Industry and construction	3597	4704	6114	7913
Agriculture and fishing	189	240	280	327
Transportation	28393	33009	38621	44888
Services (inc. F.A.)	12578	14047	15912	18168
Residential	26541	32124	37789	45039
TOTAL	71298	84124	98716	116335

(1) Energy balance F.A. = French Army

8.1.2. The Growth Scenario

This scenario, which is outlined in section 6.3, assumes that the economy of Djibouti develops strongly, with a rate of growth in the GDP of 5 % annually up to the year 2000.

Industry moves ahead passing from 8.2 % of the GDP in 1985 to 13 % in 2000 ; the energy sector also takes a larger share, while agriculture grows from 4 % to 8.5 % during this period.

The service sector declines proportionately, going from 76 % at the present time to 63.5 % at the end of the period.

This scenario also assumes quite a significant increase in the level of household electrification.

The results of the simulation of this scenario are presented in Tables 8.1.3 and 8.1.4.

Table 8.1.3 Growth Scenario - Energy Demand, TPE

	1985 (1)	1990	1995	2000
LPG	623	916	1379	2346
Kerosene	10096	12867	16795	21893
Gasoline	10613	11758	13270	15815
Diesel fuel	22425	28966	37868	50300
Jet fuel	4506	5809	7414	9462
Sub total	48263	60316	76726	99816
Electricity	12018	14828	19470	26655
Wood	10175	11036	9823	8150
Charcoal	842	1073	1259	1562
Renewable energy	-	449	1726	4391
TOTAL	71298	87702	109004	140574

1. Energy balance

Table 8.1.4 Growth Scenario - Demand by Sector, TPE

	1985(1)	1990	1995	2000
Industry and construction	3597	5007	7063	10247
Agriculture and fishing	189	280	343	430
Transportation	28393	35561	45819	61421
Services (inc. F.A.)	12578	14855	17846	21325
Residential	26541	32000	37932	47052
TOTAL	71298	87703	109003	140575

1. Energy balance F.A. = French Army

The overall demand for energy under this scenario very nearly doubles during the 15-year pericd. Disaggregated by energy type, there is a marked increase in the demand for LP Gas, which increases by a factor of more than 3. The demand for kerosene, Diesel fuel, jet fuel, and electricity more than doubles.

The demand for charcoal increases by 86 %, while the final demand for fuelwood actually decreases by 20 % -- substituted for by kerosene in this scenario. Overall, the demand for wood still increases but only slightly.

By sector, this scenario predictably shows a strong increase in energy demand for the industrial and construction sector, as well as for agriculture and fishing. The energy demand imposed by the transportation sector also more than doubles.

8.1.3. Evolution of the Demand for Electricity

Given the importance of electricity in energy supply and hence energy planning in Djibouti, it is essential that the future demand for this particular form of energy be carefully evaluated and assessed.

It should first be recalled that MEDEE-S is a model of final demand, i.e. a model of energy consumption not of energy production. In order to estimate the production of electricity given the projection of final demand, one must take into account the consumption of electricity which takes place in the power stations themselves, as well as the energy losses which occur in the electrical transmission and distribution system.

During the period 1981-1985, in-house or auxiliary consumption by EdD averaged 7.5 % of production, while transmission and distribution losses accounted for 12.9 % of net production /8.1/.

Assuming that these numbers decrease slightly in the future, a figure of 18 % has been used to calculate the difference between electricity production and consumption. The evolution of the production of electricity according to the 2 scenarios modelled by MEDEE-S is shown below in Table 8.1.5.

Table 8.1.5 Evolution of the Demand and Production of Electricity

	REFERENCE SCENARIO			GROWTH SCENARIO		
	1990	1995	2000	1990	1995	2000
Final demand GWh/year	164.1	195.1	235.6	172.4	226.7	309.9
Production GWh/year (1)	200.1	238.0	287.3	210.3	276.1	378.0
Average annual rate of growth (from 1985), %	4.0	3.8	3.8	5.1	5.3	5.7

1. Losses and auxiliary consumption taken as 18 % of production.

It should be noted that the projection of the production of electricity presented in the study by Petcu /8.1/, which was itself based on the projections made by EdD, envisions a growth in the production of electricity even higher than that estimated by MEDEE-S under the growth scenario.

Figure 8.1.1 shows the 3 projections : that of Petcu, and the 2 curves generated by the MEDEE-S model.

The difference between the growth scenario and that of Petcu is not that large - a difference of 7 % in the year 2000 But the reference scenario of MEDEE-S generates a production curve which is markedly lower : 30 % lower at the end of the period.

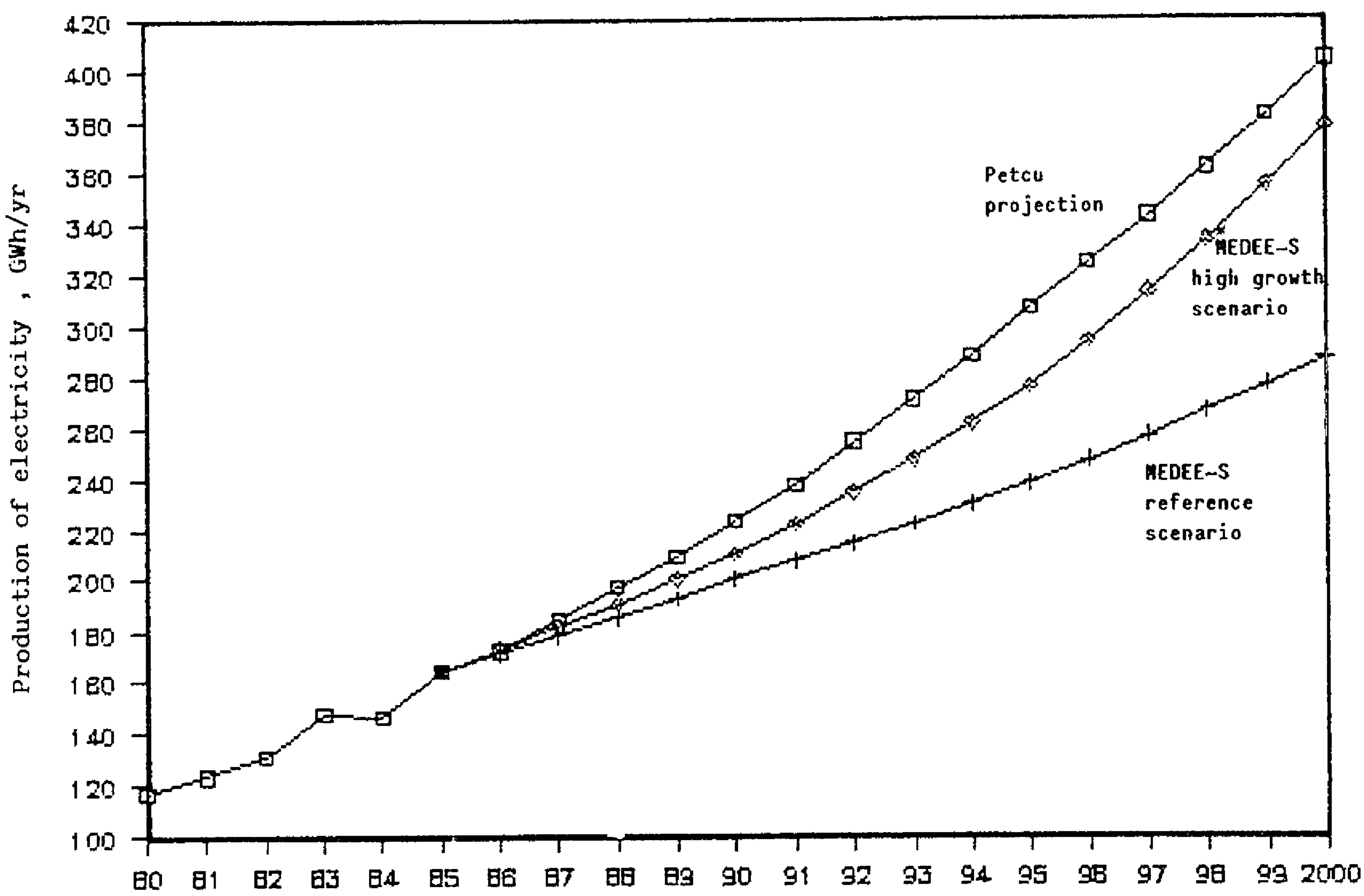


Figure 8.1.1. Evolution of the Production of Electricity
According to the Different Scenarios

A review of the latest data on the economic development of Djibouti does not provide evidence supporting the electricity demand projections presented by Petcu, or even those generated by the growth scenario simulated by MEDEE-S.

The evolution in the demand for electricity estimated by the MEDEE-S model under the reference scenario should be considered the more realistic projection, and it is this projection which is used in this study for the purposes of energy planning.

In support of this argument, it should be noted that the most recent figures from EdD for 1986 show that the production of electricity was approximately 170 GWh (including the District centres), a figure almost precisely that estimated by the MEDEE-S model under the reference scenario.

However, the projection made by Petcu, and the growth scenario modeled by MEDEE-S, both estimate production at about 172 GWh, an increment 25 % larger than that which actually occurred between 1985 and 1986.

8.2. POSSIBLE SCENARIOS FOR THE PROVISION OF FINAL ENERGY

8.2.1. Fuelwood and Petroleum Products

In 1985, the final demand for energy was provided by the following sources of energy:

- wood and wood charcoal	15%
- petroleum products	68%
- electricity	17%

Renewable energy resources--solar and wind energy--still play only a very minor role in the supply of energy.

It is assumed in this study that there will be sufficient supplies of petroleum products available internationally through the period until the year 2000. Although exceptional circumstances may always intervene, it is not considered likely that, during the next 15 years, a serious restriction in the physical supply of petroleum fuels will occur.

During this same period, the availability of dead wood for cooking and for the production of charcoal would appear to be sufficient, an assumption, however, which should be validated by a more detailed study of biomass resources.

In view of the above, it is notably the supply of electricity which requires a detailed analysis. The possible scenarios for the development of the electricity supply system are discussed in the section which follows.

8.2.2. The Development of the Electrical Power System

The nature of electrical power supply requires that it be generated in response to the demand, and supplied to the points of consumption via a transmission and distribution network. The supply of electricity therefore depends on the capacity of the generating system to respond at any given moment to the demand imposed by all the consumers linked to the system. Consequently, with regard to electricity supply, it is the total electricity system which must be considered: power stations, and the transmission and distribution system.

The scenarios considered for the future generation of electricity are:

a) Electricity produced by additional Diesel generators
b) Geothermal power
c) Coal-fired power generation
d) Hydropower generation at Lac Assal
e) Development of solar power stations.

These options might also be combined in an optimal manner depending on the future development of the electricity system.

It should also be noted that these options do not in any way exclude the generation of electricity in the rural areas of the country by small-scale renewable energy systems such as photovoltaic panels or wind turbines.

These options can be classified in the following manner:

- Those capable of implementation before the year 2000: options a, b and c.

- A backup option for the same period: option c.

- Those options probably only possible to implement after the year 2000: option d (if studies confirm the technical and economic feasibility of such an installation); and option e (if the development of solar energy technologies, both photovoltaic and solar thermal, continues to progress, and if the cost of electricity from these systems becomes competitive with the cost of electricity from the technologies now in operation in Djibouti).

8.2.3. Presentation of the Scenarios

Noting the reservations outlined above, the principal characteristics of the different scenarios may be described as follows:

Scenario A: Additional Diesel Generators

Three projections of the demand for electricity were presented earlier in this chapter: a projection based on the reference scenario of the MEDEE-S model which is considered here as the most plausible scenario; a projection based on the high-growth scenario of MEDEE-S; and a forecast based on the work of Petcu /8.1/ which gives rise to the highest projected electricity demand.

Although the latter forecast is considered extreme, it is this projection which has been used for estimating the equipment and the investment necessary for supplying sufficient electrical energy to meet the projected demand. Table 8.2.1 presents data relative to this scenario, and shows that EdD's present capacity, together with the addition of the 2 new 5.5 MW generators, is sufficient to accomodate the anticipated future electricity demand.

Scenario B: Development of Geothermal Power

Depending on the progress of the program of geothermal exploration and development, a geothermal power plant will be gradually installed and integrated into the power generation and distribution system. The generation of electricity by Diesel generators, and therefore the consumption of petroleum products, will continue to remain substantial up to the year 2000.

Scenario C: Coal-Fired Power Generation

This scenario, the viability of which depends to a great extent on the price of imported coal, should be considered as a reserve scenario. This option could intervene for the generation of base load power given a minimum installed capacity and a secure supply of fuel. A study of coal-fired power generation could be conducted whenever appropriate, depending on the evolution of the price of coal.

The evolution in the relative prices of coal and petroleum will be a principal factor in the decision to proceed with such a study. However, the electrical base load must be large enough to accomodate a coal-fired plant of a viable capacity.

Scenario D: Hydroelectric Power

The novel idea of using the difference in elevation (150 m) between the sea and Lac Assal to produce hydroelectric power is one that should be tentatively studied.

The distance between the gulf of Tadjourah and Lac Assal is only 12 km. If the seismic characteristics of the terrain prove to be acceptable, it would be relatively simple for the sea water to pass through a subterranean conduit descending from the gulf to the lake.

However, the terrain is seismically active, and this may well preclude the realisation of such a project.

Alternatively, a surface conduit could be considered. This approach would involve certain difficulties such as having to lift the water over the intervening hills before it could drop 300 m into the lake.

In this case, it might be useful to examine the possibility of storing the water in a reservoir in the hills, thus permitting an arrangement which could respond more flexibly to peak electrical demand.

Scenario E: Solar Power Generation

As mentioned previously, this scenario is offered as an option for the future. The technical and economic development of solar power generation will need to be carefully monitored in order to identify the moment when the technology becomes a realistic and viable option for Djibouti.

8.2.4. Description and Analysis of Scenarios

As discussed earlier, only scenarios A and B can be considered as realistic options for producing electric power during the period from the present until the year 2000. A more detailed analysis of these options has therefore been performed.

Unfortunately, at the present time, the available technical and economic data are not yet sufficiently precise to permit a detailed analysis of the geothermal scenario.

The potential of the geothermal resource is still under study; only after March 1987 will the first practical information become available.

The present study cannot therefore present a detailed analysis of the geothermal scenario. In fact, this option could not intervene before 1992-1994, which is the time when additional generating capacity will become necessary.

By that time, the information and data on geothermal energy will be sufficient to allow a detailed comparison of the economics of geothermal and Diesel electric power generation.

8.2.4.1. Scenario A - Diesel Electric

As noted above, scenario A concerns not only the extension of the Boulaos power station, but also the transmission and distribution of electricity, and the generation of power in the District centres outside of the principal network.

Two 5.5 MW Diesel generators are currently being installed at Boulaos.

Even for the demand forecast made by Petcu /8.1/, the existing EdD capacity should be able to meet demand until 1992-1994. By that time, a third 15 MW generator will need to be installed, followed by a fourth unit a year or two later. This evolution is shown in Table 8.2.1.

It can be seen that the growth in installed capacity is practically equal to the demand (1 kW installed for 1 kW requested), this characteristic being due to a progressive decrease of the level of overcapacity necessary to meet the projected load.

Table 8.2.1. Evolution of the Installed Capacity of the Electricity Generating System of Djibouti

Year	Production of electricity GWh	Present installed capacity MW (1)		New units MW		Total installed capacity MW
1985	164.2					
1986	169.6	74.5				74.5
1987	181.4	74.5				74.5
1988	190.6	74.5				74.5
1989	200.3	70.5				70.5
1990	210.6	70.5		11		81.5
1991	221.3	70.5		"		81.5
1992	232.6	70.5		"		81.5
1993	244.4	61.5		"		72.5
1994	256.9	61.5		15		87.5
1995	270.0	61.5		15		102.5
1996	283.8	61.5		"		102.5
1997	298.2	61.5		"		102.5
1998	313.4	61.5		15		117.5
1999	329.4	61.5		"		117.5
2000	346.2	61.5		"		117.5
Structure in 2000		61.5	+	56	=	117.5

1. This projection is that proposed by Petcu /8.1/. The other socio-economic scenarios modeled by this study produce demand projections significantly inferior to that shown in the table above. The installed capacity necessary to accomodate the demand in the latter cases would therefore be reduced commensurately.

<u>Economic Analysis of Scenario A: Diesel Electric</u>

Annex 8.1 presents an economic analysis of the cost of scenario A through to the year 2000. This assumes electricity production by Diesel generators which, together with the existing generators, respond to a strong growth in electricity demand.

With regard to power generation in the Districts, expansion based on Diesel electric generators will continue with the installation of new generators (each 100 to 200 kW) according to the level of demand in each District.

The relocation of generators from one District to another will permit the Districts to respond to the demand in an effective manner without unduly increasing the number of generators in any one District. This approach, which is very effective economically, could significantly reduce the cost of installation and operation.

The interconnection of adjacent secondary centres is justified when this permits the concentration of installed capacity in order to reduce operating costs. This was the objective in interconnecting the centres at Dikhil and Ali Sabieh.

The interconnection of the secondary centres with the main network may be even more effective since it would permit the power generated by the small Diesel generators running on Diesel fuel in the Districts, to be replaced by power generated in Djibouti ville by large Diesel generators running on fuel oil. The difference in fuel costs could, in certain cases, justify the interconnection even if the investment required is greater than the cost of increasing the District capacity.

The Djibouti-Tadjourah interconnection is a good example. Without interconnection, the Tadjourah system will be saturated by 1988 or 1989 and additional generators will need to be installed. The most economic way of increasing capacity would be to systematically replace the existing 400 kW generators with 1250 kW generators. This would cost 1,220 MFD over the period until the year 2000, or 665 MFD in 1987 currency at a discount rate of 8 %.

In contrast, a transmission line of 60 kW would cost 830 MFD and would save 5.14 FD/kWh (May 1986 prices) in fuel costs. The total discounted cost of this option is 369 MFD, or 296 MFD less than the cost of local power production. The interconnection is therefore the most economic alternative and should be undertaken.

8.2.4.2. Scenario B - Geothermal Energy

Bearing in mind the comments made earlier concerning the lack of precise data regarding this option, in the event that the exploratory phase of the geothermal program proves to be successful, the development of the resource is envisaged as follows:

- the drilling of 3 wells to confirm previous data; each estimated to have a 67% chance of success; and each producing 6 MW.

- the drilling of 6 production wells; each with an 83% chance of success and each producing 6MW.

- studies and tests of the wells, the engineering systems, and the reservoirs.

- construction of a 132 kV transmission line, with a total length of 160 km, from the Hanlé Plain through Dikhil and Ali Sabieh to Djibouti ville.

- installation of a system for transporting and discharging the geothermal fluid.

- installation of a geothermal power plant the design and capacity of which will depend on the temperature and flowrate of the geothermal fluids.

As a first approximation, the geothermal power plant considered in the prefeasibility study conducted by Aquater can be used as a working hypothesis /8.2/. This power plant consists of 3 or 4 generators, each 7 MW, to be constructed, at the earliest, between 1991 and 1992.

Economic Analysis of Scenario B: Geothermal Energy

The costs of a geothermal power plant have been evaluated in the study undertaken by Aquater cited above, and in a comparative study of geothermal and Diesel-electric options conducted by OPEC in September 1983 /8.3/.

Since no additional data are yet available on the geothermal option, the analysis conducted in this study looks at the influence of the price of oil and the temperature of the geothermal fluid on the economics of power generation, as well as commenting on the feasibility of the project as a whole.

This analysis is of some interest, however, since previous studies were based on only one fluid temperature (220 °C), and on only one petroleum price--the price of petroleum at the time the studies were conducted.

On the basis of the OPEC study, annex 8.2. presents in Figures A 8.2.1. and A 8.2.2. the variation of the cost of electricity from geothermal energy as a function of fluid temperature (between 220 °C and 280 °C), and as a function of the cost of petroleum (between $10 and $25 per barrel).

The results of this analysis are compared with the cost of electricity from an equivalent Diesel electric system, for a range of interest rates.

These graphs underscore two essential points:

- there is a very good chance that geothermal power will be competitive with Diesel electric systems;

- the temperature of the geothermal fluid has a significant impact on the economic viability of the geothermal project.

REFERENCES

8.1. Petcu, M., "Perspectives de développement du système électrique et tarification de l'électricité", Rapport de mission, ISERST/PNUD, 1986.

8.2. "Technical-Economic Study of Geothermal Pre-Feasibility" Aquater, ISERST, and Direction de la Planification, Djibouti, 1982.

8.3. "Appraisal of the Geothermal Exploration Project in the Republic of Djibouti", Report No. DJ-2, the OPEC fund for International Development, 1983.

ANNEX 8.1 PRESENT VALUE OF SCENARIO A -- DIESEL ELECTRIC

A.8.1.1. Investments

Unit Cost of New generators

The costs used here are taken from Annex A 6.1 of the report by Petcu /8.1/; that is: 6,553 MFD, from which is subtracted the cost of the Boulaos G 21 and G 22 generators: 1493 MFD.

The remainder, 5,060 MFD, divided by the power envisioned by Petcu, 41 MW, yields a cost of 123.4 MFD/MW. This value is used in the analysis which follows.

Disbursements

The schedule of disbursements is assumed to be as follows:

Year	%
- 2	10
- 1	40
year of startup	40
+ 1	10

Power Transmission

These figures are again taken from the report by Petcu /8.1/

Power Distribution

The values for the period 1985-1995 are taken from Petcu. Values for the period 1995-2000 were calculated from a linear extrapolation of the figures for 1990-1995.

Miscellaneous Expenses

These figures are identical to those of Petcu /8.1/.

Salvage Value

The salvage value was calculated solely for the generators and power lines.

Operation and Maintenance

The cost of operation and maintenance per GWh/an is again based on the report by Petcu /8.1/, except that the figures in that report, which are in 1983 dollars, have been increased by 10%.

Fuel Costs (fuel oil, Diesel fuel, and lubricants)

The cost of fuel and lubricants is taken from the report by Petcu.

The results of this analysis are shown in Table A 8.1.1.

TABLE A 8.1.1

PRESENT VALUE OF THE DIESEL SCENARIO

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Salvage Value	Present value 5%	10%	15%
Production of electricity, GWh/year	170.9	177.8	184.9	192.4	200.1	207.2	214.5	222.0	229.9	238.0	247.1	256.6	266.5	276.7	287.3				
New generators, MW					2 X 5.5				15	15			15						
Investments, MFD	554	1622	1914	1396	1186	777	871	1656	2657	2009	1186	1641	1681	1166	1021	-6016			
- Generators			136	543	543	136	185	925	1460	925	370	740	740	185		-4682			
- Transmission lines		730	855	135					400	270						-1334			
- Distribution lines	301	275	292	304	337	351	416	451	477	514	516	601	641	681	721				
- Miscellaneous	253	617	631	414	306	290	270	280	300	300	300	300	300	300	300				
Operation and maintenance, MFD	1071	1103	1148	1194	1242	1286	1331	1378	1427	1477	1534	1593	1654	1718	1784				
Fuel costs, MFD																			
- at an oil price of 15 US$/bbl	1135	1193	1253	1317	1385	1455	1529	1607	1689	1775	1866	1961	2061	2166	2276				
- at an oil price of 20 US$/bbl	1400	1472	1547	1625	1709	1795	1887	1983	2085	2191	2303	2420	2543	2673	2809				
- at an oil price of 25 US$/bbl	1607	1692	1778	1868	1964	2064	2169	2279	2396	2518	2647	2781	2923	3072	3229				
TOTAL, MFD																			
- at an oil price of 15 US$/bbl	2760	3918	4315	3907	3813	3518	3732	4641	5773	5261	4586	5195	5396	5049	5081	-6016	42156	30630	23241
- at an oil price of 20 US$/bbl	3025	4197	4608	4215	4137	3859	4090	5017	6168	5677	5023	5653	5876	5556	5614	-6016	45974	33314	25228
- at an oil price of 25 US$/bbl	3232	4417	4840	4458	4393	4127	4372	5314	6480	6004	5367	6015	6258	5956	6033	-6016	48981	35426	26792

ANNEX 8.2 ECONOMIC ANALYSIS OF GEOTHERMAL POWER

A 8.2.1 Introduction and Background

The technical and economic analysis of geothermal energy in Djibouti can be found in 2 principal studies:

1. "Technical-Economic Study of Geothermal Pre-Feasibility", AQUATER, March 1982.

2. "Appraisal of the Geothermal Exploration Project in the Republic of Djibouti", the OPEC Fund, September, 1983.

The economic analyses are based on:

a) data and information on the geothermal resource available at the time of the study, and on data taken from geothermal projects in other countries assumed to be applicable to Djibouti.

b) the cost of petroleum and scenarios related to its growth, i.e. US$ 29 in 1982, US$ 33 in 1983.

The economic analysis set out in the OPEC study is based on the previous study by Aquater. As a result of the favorable conclusions of these studies, the program of exploratory drilling was commenced.

Between the period when these studies were conducted and the present time, significant changes have occured in the petroleum market: the price of petroleum dropped from US$ 29-33 /bbl in 1982-83 to US$ 8-9/bbl in 1986; rising again to US$ 14-15/bbl by the end of 1986.

As a result, the assumptions made in the studies cited above concerning the future price of petroleum, and the analyses carried out regarding the economic viability of the alternative methods of electricity production, can no longer be considered valid.

It is therefore appropriate to rework the previous analyses, and to determine the extent to which the economics of geothermal energy have been shifted by the changes in petroleum prices and other technical and economic factors.

It will not be until the end of the exploration program that more specific and reliable data will become available. A definitive economic evaluation of geothermal energy in Djibouti can then be performed.

A 8.2.2 Methodology Employed

The economic analysis evaluates the cost per kWh of electricity for both Diesel-electric and geothermal power generation. The basic data and the costs used in the OPEC study are reproduced in Tables A 8.2.1. and A 8.2.2.

Table A 8.2.1. Basic Technical Data for the Geothermal Project

1. Net installed capacity	20 MW
2. Average power per well	4 MW
3. Total number of wells drilled	10
4. Number of reinjection wells	1
5. Average annual reduction in output per well	4 %
6. Total number of maintenance wells	6
7. Mobile pilot plant capacity	1 MW
8. Energy production	
- 1st year of production	33 GWh
- 2nd year of production	65 GWh
- 3rd year of production	94 GWh
- 4th year of production (full output)	130 GWh
9. Investments (millions US $/1983)	93.90
9.1 exploration wells	12.1
9.2 development wells	15.8
9.3 injection and maintenance wells	11.1
9.4 transmission lines	16.0
9.5 power plant systems	38.9
10. Period of the economic analysis	20 yrs
11. Labour costs (millions US $/1983)	0.5
12. Annual cost of maintenance	1.7
13. Other costs	0.3

Source: The OPEC Fund study /8.3/.

Table A 8.2.2. Basic Technical and Economic Data for Diesel Electric Power Generation

1. Capacity	30	MW
2. Production	138	GWh/year
3. Fuel consumption		
3.1. fuel oil	225	g/kWh
3.2. Diesel fuel	2,500	t/year
3.3. lubricants	2	g/kWh
4. Investments	850	US $/kW/(1983)
5. Economic lifetime	20	years
6. Power plant utilization	4,600	hrs/year
7. Average cost of each employee	7,750	US $/1983
8. Number of employees	238	
9. Annual cost of maintenance	4	% of investment
10. Other management costs	6	% of investment

Source: The OPEC Fund study /8-3/.

The price of fuel and lubricants were calculated as shown in section A 8.2.3.

The cost per kWh of electricity was calculated as follows:

$$\text{cost per kWh} = \frac{\sum_{c=1}^{n} di}{\sum_{c=1}^{n} Ei}$$

where: di = total annual expenditures in year i
Ei = production of electricity in year i
n = economic lifetime

A sensitivity analysis with respect to the price of petroleum and the temperature of the geothermal fluid was also conducted.

Concerning the price of petroleum, the sensitivity analysis considers a range of average petroleum prices over the lifetime of the project: 28 years.

This sensitivity analysis was carried out for a range of fluid temperatures, since higher fluid temperatures can produce more electricity. The increase in electrical production as a function of fluid temperature is shown in the table below.

Fluid temperature, °C	GWh/year	increase in production
220	130	reference case
240	159	+ 22.5 %
260	191	+ 47.3 %
280	230	+ 77.2 %

In addition, two investment cases were considered:

a) the first case included all the costs identified in the OPEC study, as shown below:

	million US $/1983	%
exploration wells	12.1	13
development wells	15.8	17
maintenance wells	11.1	12
transmission lines	16.0	17
power plant systems	38.9	41
TOTAL	93.9	100

b) the second case excluded the cost of the exploratory wells. This cost, 13 % of the total, was considered as a "sunk cost", since the work has already been undertaken.

When the program of exploration which is now in progress provides accurate and reliable data on the geothermal resource, these economic analyses will obviously be refined. However, the final economic analysis should not incluae the cost of the exploratory wells.

A 8.2.3. The Price of Fuel and Lubricants

In order to analyze the effect of variations in the price of petroleum, the changes in the price of fuel (fuel oil and Diesel fuel) and lubricants were estimated as a function of the FOB price of petroleum.

The components considered are as follows:

- FOB price of fuel oil (PFFO)
- CIF price of fuel oil (PCFO)
- pre-tax price of fuel oil paid by EdD (PFHT)

The FOB price of fuel oil (PFFO) is taken to be 90 % of the FOB price of petroleum (PFP).

On the basis of data provided by EdD and shown in Table A 8.2.3, the equations linking the price of fuel oil to the price of petroleum were determined.

Table A 8.2.3. Price of Fuel Oil Delivered to EdD, $/tonne

Date	PFHT	PCFO	PFFO	RATIOS	
				PFHT/PFFO	PCFO/PFFO
June 1986	117.46	96.55	81.44	1.44	1.184
July 1986	162.83	128.86	116.40	1.39	1.107
August 1986	95.41	74.55	59.11	1.61	1.261

PFHT = pre tax price of fuel oil paid by EdD.
PCFO = CIF price of fuel oil paid by EdD.
PFFO = FOB price of fuel oil paid by EdD.
(source: EdD; all prices are US$ 1986 per tonne)

The analytical functions are as follows:

$$PFHT = PFP \times 0.90\,(1.7907674 - 0.00242012\ PFP)$$

$$PCFO = PFFO\,(1.4116626 - 0.0026503\ PFP)$$

Figure A 8.2.1. shows the values of PFHT, PCFO, and PFFO as a function of the price of petroleum (PFP).

The price of Diesel fuel and of lubricants was estimated on the basis of the following ratios:

Price FOB Diesel fuel / PFFO = 1.54
Price FOB lubricants / PFFO = 1.54

A.8.2.4. Foreign Exchange Costs

For each year of the project, the foreign exchange balance was calculated, i.e. the difference in expenditures in foreign exchange with or without the geothermal project.

This calculation was based on an estimation of the fraction of the various costs attributable to foreign exchange, as shown in the following table:

Geothermal energy	% foreign exchange
Exploration wells	90
Development wells	90
Maintenance wells	90
Transmission lines	90
Power plant	90
Operation and maintenance	34
Diesel electric	
Investments	90
Operation and maintenance	19
Fuels and lubricants	
-FOB petroleum price = 10 $US/bbl	87
-FOB petroleum price = 15 $US/bbl	79
-FOB petroleum price = 20 $US/bbl	79
-FOB petroleum price = 25 $US/bbl	79

For the fuels and lubricants, the foreign exchange contribution is estimated from the data shown in Table A 8.2.2 and the functions set out in section A 8.2.3.

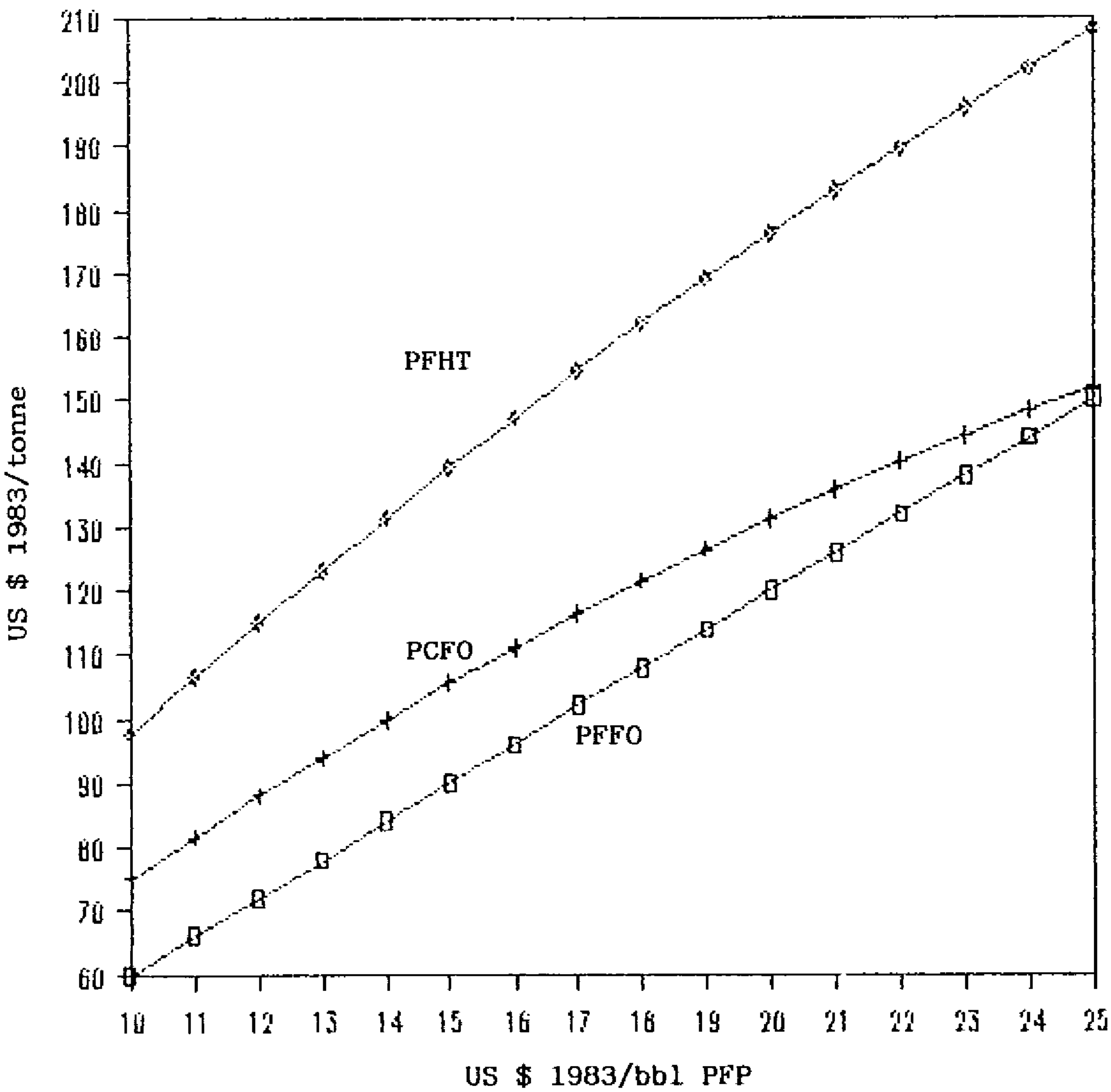


Figure A8.2.1. Variations in the Price of Fuels

PFHT	:	Price of fuel oil ex.tax paid by EdD
PCFO	:	Price CIF fuel oil paid by EdD
PFFO	:	Price FOB fuel oil paid by EdD
PFP	:	Price FOB of oil

A 8.2.5. Results

Table A 8.2.5 provides the following information:

a. Annual expenditures for the geothermal project (including the cost of exploratory drilling) and those foreseen for the Diesel electric alternative.

b. The annual foreign exchange balance for the two alternatives (for a geothermal temperature of 220 °C), for a range of petroleum prices.

c. Annual geothermal electricity production for a range of temperatures, and annual Diesel electric production.

d. The present value of total costs, electricity production, and foreign exchange discounted at 5 %, 10 %, and 15%.

e. The unit cost per kWh of electricity of each alternative.

Table A 8.2.6. presents the same analysis but excluding the cost of exploratory drilling.

Table A 8.2.7. presents a summary of the principal results.

Figure A 8.2.2. shows graphically the cost per unit of electricity for the two alternatives, where the cost of the exploratory wells is included for the geothermal case. Figure A 8.2.3 presents the results of the analysis with the cost of the exploratory wells excluded.

From these data, it appears that thresholds of economic viability for the geothermal project are as follows:

	fluid temperature °C	Average price of petroleum 1986-2013
Including the cost of the exploratory wells	220	30 US$ 1986/bbl
	240	14 "
Excluding the cost of the exploratory wells	220	16 US$ 1986/bbl
	240	8 "

TABLE A 8.2.5 ECONOMIC ANALYSIS OF THE PRODUCTION OF ELECTRICITY FROM GEOTHERMAL ENERGY — INCLUDING THE COST OF EXPLORATION

	EXPENDITURES (MILLIONS US$ 1983)																			
	YEAR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
GEOTHERMAL																				
1.INVESTMENTS	1.6	5.1	5.4	18.2	16.6	4.9	9	14	8	1.7	0	0	0.9	0	1.7	0	0	0	0	1.7
1.1 EXPLORATION WELLS	1.6	5.1	5.4																	
1.2 DEVELOPMENT WELLS				8.7	7.1															
1.3 MAINTENANCE WELLS										1.7			0.9		1.7					1.7
1.4 TRANSMISSION LINES				8	8															
1.5 POWER STATION				1.5	1.5	4.9	9	14	8											
2.OPERATION AND MAINTENANCE						2.2	2.2	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
3.TOTAL COSTS	1.6	5.1	5.4	18.2	16.6	7.1	11.2	16.5	10.5	4.2	2.5	2.5	3.4	2.5	4.2	2.5	2.5	2.5	2.5	4.2
4. ANNUAL PRODUCTION, GWh/YR																				
-At 220 C (reference)						33	65	94	130	130	130	130	130	130	130	130	130	130	130	130
-At 240 C						40	80	115	159	159	159	159	159	159	159	159	159	159	159	159
-At 260 C						49	96	138	191	191	191	191	191	191	191	191	191	191	191	191
-At 280 C						58	115	167	230	230	230	230	230	230	230	230	230	230	230	230
DIESEL																				
1.INVESTMENTS				10.2	15.3															
2.OPERATION AND MAINTENANCE						4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
3.FUEL (fuel oil and Diesel fuel) AND LUBRICANTS																				
- At an oil price FOB of 10 US$/bbl						3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34
- At an oil price FOB of 15 US$/bbl						4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66
- At an oil price FOB of 20 US$/bbl						5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75
- At an oil price FOB of 25 US$/bbl						6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60
4.TOTAL COSTS																				
- At an oil price FOB of 10 US$/bbl	0.00	0.00	0.00	10.20	15.30	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74
- At an oil price FOB of 15 US$/bbl	0.00	0.00	0.00	10.20	15.30	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06
- At an oil price FOB of 20 US$/bbl	0.00	0.00	0.00	10.20	15.30	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15
- At an oil price FOB of 25 US$/bbl	0.00	0.00	0.00	10.20	15.30	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
5.ANNUAL PRODUCTION, GWh/YEAR						138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
6.FOREIGN EXCHANGE BALANCE GEOTHERMAL-DIESEL (*)																				
- At an oil price FOB of 10 US$/bbl	1.44	4.59	4.86	7.20	1.17	1.42	5.11	9.71	4.31	-1.36	-2.89	-2.89	-2.08	-2.89	-1.36	-2.89	-2.89	-2.89	-2.89	-1.36
- At an oil price FOB of 15 US$/bbl	1.44	4.59	4.86	7.20	1.17	0.64	4.33	8.94	3.54	-2.13	-3.66	-3.66	-2.85	-3.66	-2.13	-3.66	-3.66	-3.66	-3.66	-2.13
- At an oil price FOB of 20 US$/bbl	1.44	4.59	4.86	7.20	1.17	-0.22	3.47	8.07	2.67	-3.00	-4.53	-4.53	-3.72	-4.53	-3.00	-4.53	-4.53	-4.53	-4.53	-3.00
- At an oil price FOB of 25 US$/bbl	1.44	4.59	4.86	7.20	1.17	-0.90	2.79	7.40	2.00	-3.67	-5.20	-5.20	-4.39	-5.20	-3.67	-5.20	-5.20	-5.20	-5.20	-3.67

(*) Assuming temperatures of 220 Centigrade

TABLE A B.2.5 Continued

	EXPENDITURES (M$ 1983)									TOTAL DISCOUNTED COSTS, TDC (M$ 1983)			TOTAL PRODUCTION DISCOUNTED, TPD (GWh)			RATIO TDC/TPD (Centimes $US/kWh)		
	YEAR 21	22	23	24	25	26	27	28	TOTAL M$	At 5%	At 10%	At 15%	At 5%	At 10%	At 15%	At 5%	At 10%	At 15%
GEOTHERMAL																		
1.INVESTMENTS	0	0	1.7	0	0	1.7	0	1.7	93.9									
1.1 EXPLORATION WELLS									12.1									
1.2 DEVELOPMENT WELLS									15.8									
1.3 MAINTENANCE WELLS			1.7			1.7		1.7	11.1									
1.4 TRANSMISSION LINES									16									
1.5 POWER STATION									38.9									
2.OPERATION AND MAINTENANCE	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5										
3.TOTAL COSTS	2.5	2.5	4.2	2.5	2.5	4.2	2.5	4.2		93.9	65.3	48.5						
4. ANNUAL PRODUCTION, GWh/YR																		
-At 220 C (reference)	130	130	130	130	130	130	130	130					1231.0	612.1	335.4	7.63	10.66	14.47
-At 240 C	159	159	159	159	159	159	159	159					1508.0	749.9	410.9	6.23	8.70	11.81
-At 260 C	191	191	191	191	191	191	191	191					1813.2	901.7	494.1	5.18	7.24	9.83
-At 280 C	230	230	230	230	230	230	230	230					2181.3	1084.7	594.4	4.31	6.02	8.17
DIESEL																		
1.INVESTMENTS									25.5									
2.OPERATION AND MAINTENANCE	4.4	4.4	4.4	4.4	1.4	1.4	1.4	1.4										
3.FUEL (fuel oil and Diesel fuel) AND LUBRICANTS																		
- At an oil price FOB of 10 US$/bbl	3.34	3.34	3.34	3.34	1.09	1.09	1.09	1.09										
- At an oil price FOB of 15 US$/bbl	4.66	4.66	4.66	4.66	1.52	1.52	1.52	1.52										
- At an oil price FOB of 20 US$/bbl	5.75	5.75	5.75	5.75	1.87	1.87	1.87	1.87										
- At an oil price FOB of 25 US$/bbl	6.60	6.60	6.60	6.60	2.15	2.15	2.15	2.15										
4.TOTAL COSTS																		
- At an oil price FOB of 10 US$/bbl	7.74	7.74	7.74	7.74	2.49	2.49	2.49	2.49		96.4	57.4	37.5				7.11	7.86	8.73
- At an oil price FOB of 15 US$/bbl	9.06	9.06	9.06	9.06	2.92	2.92	2.92	2.92		109.3	64.4	41.6				8.06	8.81	9.69
- At an oil price FOB of 20 US$/bbl	10.15	10.15	10.15	10.15	3.27	3.27	3.27	3.27		120.1	70.2	45.0				8.85	9.60	10.48
- At an oil price FOB of 25 US$/bbl	11.00	11.00	11.00	11.00	3.55	3.55	3.55	3.55		128.5	74.8	47.7				9.47	10.22	11.10
5.ANNUAL PRODUCTION, GWh/YEAR	138	138	138	138	45	45	45	45					1356.2	731.2	429.8			
6.FOREIGN EXCHANGE BALANCE GEOTHERMAL-DIESEL (*)																		
- At an oil price FOB of 10 US$/bbl	-2.89	-2.89	-1.36	-2.89	-0.36	1.17	-0.36	1.17		14.90	16.57	15.64						
- At an oil price FOB of 15 US$/bbl	-3.66	-3.66	-2.13	-3.66	-0.62	0.91	-0.62	0.91		7.27	12.46	13.22						
- At an oil price FOB of 20 US$/bbl	-4.53	-4.53	-3.00	-4.53	-0.90	0.63	-0.90	0.63		-1.19	7.90	10.54						
- At an oil price FOB of 25 US$/bbl	-5.20	-5.20	-3.67	-5.20	-1.12	0.41	-1.12	0.41		-7.86	4.30	8.43						

(*) Assuming temperatures of 220 Centigrade

TABLE A 8.2.6 ECONOMIC ANALYSIS OF THE PRODUCTION OF ELECTRICITY FROM GEOTHERMAL ENERGY — EXCLUDING THE COST OF EXPLORATION

	EXPENDITURES (MILLIONS US$ 1983)																			
	YEAR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
GEOTHERMAL																				
1. INVESTMENTS	0	0	0	18.2	16.6	4.9	9	14	8	1.7	0	0	0.9	0	1.7	0	0	0	0	1.7
1.1 EXPLORATION WELLS																				
1.2 DEVELOPMENT WELLS				8.7	7.1															
1.3 MAINTENANCE WELLS										1.7			0.9		1.7					1.7
1.4 TRANSMISSION LINES				8	8															
1.5 POWER STATION				1.5	1.5	4.9	9	14	8											
2. OPERATION AND MAINTENANCE						2.2	2.2	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
3. TOTAL COSTS	0	0	0	18.2	16.6	7.1	11.2	16.5	10.5	4.2	2.5	2.5	3.4	2.5	4.2	2.5	2.5	2.5	2.5	4.2
4. ANNUAL PRODUCTION, GWh/YR																				
-At 220 C (reference)						33	65	94	130	130	130	130	130	130	130	130	130	130	130	130
-At 240 C						40	80	115	159	159	159	159	159	159	159	159	159	159	159	159
-At 260 C						49	96	138	191	191	191	191	191	191	191	191	191	191	191	191
-At 280 C						58	115	167	230	230	230	230	230	230	230	230	230	230	230	230
DIESEL																				
1. INVESTMENTS				10.2	15.3															
2. OPERATION AND MAINTENANCECE						4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
3. FUEL (fuel oil+Diesel fuel) AND LUBRICANTS																				
- At an oil price FOB of 10 US$/bbl						3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34
- At an oil price FOB of 15 US$/bbl						4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66
- At an oil price FOB of 20 US$/bbl						5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75
- At an oil price FOB of 25 US$/bbl						6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60
4. TOTAL COSTS																				
- At an oil price FOB of 10 US$/bbl	0.00	0.00	0.00	10.20	15.30	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74
- At an oil price FOB of 15 US$/bbl	0.00	0.00	0.00	10.20	15.30	9.06	9.06	9.06	9.06	9.56	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06
- At an oil price FOB of 20 US$/bbl	0.00	0.00	0.00	10.20	15.30	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15	10.15
- At an oil price FOB of 25 US$/bbl	0.00	0.00	0.00	10.20	15.30	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
5. ANNUAL PRODUCTION, GWh/YEAR						138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
6. FOREIGN EXCHANGE BALANCE GEOTHERMAL-THERMOELECTRIC (*)																				
- At an oil price FOB of 10 US$/bbl	0.00	0.00	0.00	7.20	1.17	1.42	5.11	9.71	4.31	-1.36	-2.89	-2.89	-2.08	-2.89	-1.36	-2.89	-2.89	-2.89	-2.89	-1.36
- At an oil price FOB of 15 US$/bbl	0.00	0.00	0.00	7.20	1.17	0.64	4.33	8.94	3.54	-2.13	-3.66	-3.66	-2.85	-3.66	-2.13	-3.66	-3.66	-3.66	-3.66	-2.13
- At an oil price FOB of 20 US$/bbl	0.00	0.00	0.00	7.20	1.17	-0.22	3.47	8.07	2.67	-3.00	-4.53	-4.53	-3.72	-4.53	-3.00	-4.53	-4.53	-4.53	-4.53	-3.00
- At an oil price FOB of 25 US$/bbl	0.00	0.00	0.00	7.20	1.17	-0.90	2.79	7.40	2.00	-3.67	-5.20	-5.20	-4.39	-5.20	-3.67	-5.20	-5.20	-5.20	-5.20	-3.67

(*) Assuming temperatures of 220 Centigrade

TABLE A 8.2.6 Continued

	EXPENDITURES (M$ 1983)									TOTAL DISCOUNTED COSTS, TDC M$, 1983			TOTAL PRODUCTION DISCOUNTED, TPD (GWh)			RATIO TDC/TPD (Centimes $US/kWh)		
	YEAR 21	22	23	24	25	26	27	28	TOTAL M$	At 5%	At 10%	At 15%	At 5%	At 10%	At 15%	At 5%	At 10%	At 15%
GEOTHERMAL																		
1.INVESTMENTS	0	0	1.7	0	0	1.7	0	1.7	81.8									
1.1 EXPLORATION WELLS									0									
1.2 DEVELOPMENT WELLS									15.8									
1.3 MAINTENANCE WELLS			1.7			1.7		1.7	11.1									
1.4 TRANSMISSION LINES									16									
1.5 POWER STATION									38.9									
2.OPERATION AND MAINTENANCE	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5										
3.TOTAL COSTS	2.5	2.5	4.2	2.5	2.5	4.2	2.5	4.2		83.1	55.5	39.7						
4.ANNUAL PRODUCTION, GWh/YR																		
-At 220 C (reference)	130	130	130	130	130	130	130	130					1231.0	612.1	335.4	6.75	9.07	11.85
-At 240 C	159	159	159	159	159	159	159	159					1508.0	749.9	410.9	5.51	7.41	9.67
-At 260 C	191	191	191	191	191	191	191	191					1813.2	901.7	494.1	4.58	6.16	8.04
-At 280 C	230	230	230	230	230	230	230	230					2181.3	1084.7	594.4	3.81	5.12	6.69
DIESEL																		
1.INVESTMENTS									25.5									
2.OPERATION AND MAINTENANCECE	4.4	4.4	4.4	4.4	1.4	1.4	1.4	1.4										
3.FUEL (fuel oil+Diesel fuel) AND LUBRICANTS																		
- At an oil price FOB of 10 US$/bbl	3.34	3.34	3.34	3.34	1.09	1.09	1.09	1.09										
- At an oil price FOB of 15 US$/bbl	4.66	4.66	4.66	4.66	1.52	1.52	1.52	1.52										
- At an ril price FOB of 20 US$/bbl	5.75	5.75	5.75	5.75	1.87	1.87	1.87	1.87										
- At an oil price FOB of 25 US$/bbl	6.60	6.60	6.60	6.60	2.15	2.15	2.15	2.15										
4.TOTAL COSTS																		
- At an oil price FOB of 10 US$/bbl	7.74	7.74	7.74	7.74	2.49	2.49	2.49	2.49		96.4	57.4	37.5				7.11	7.66	8.73
- At an oil price FOB of 15 US$/bbl	9.06	9.06	9.06	9.06	2.92	2.92	2.92	2.92		109.3	64.4	41.6				8.06	8.81	9.69
- At an oil price FOB of 20 US$/bbl	10.15	10.15	10.15	10.15	3.27	3.27	3.27	3.27		120.1	70.2	45.0				8.85	9.60	10.48
- At an oil price FOB of 25 US$/bbl	11.00	11.00	11.00	11.00	3.55	3.55	3.55	3.55		128.5	74.8	47.7				9.47	10.22	11.10
5.ANNUAL PRODUCTION, GWh/YEAR	138	138	138	138	45	45	45	45					1356.2	731.2	429.8			
6.FOREIGN EXCHANGE BALANCE GEOTHERMAL-THERMOELECTRIC (*)																		
- At an oil price FOB of 10 US$/bbl	-2.89	-2.89	-1.36	-2.89	-0.36	1.17	-0.36	1.17		5.17	7.82	7.72						
- At an oil price FOB of 15 US$/bbl	-3.66	-3.66	-2.13	-3.66	-0.62	0.91	-0.62	0.91		-2.47	3.70	5.30						
- At an oil price FOB of 20 US$/bbl	-4.53	-4.53	-3.00	-4.53	-0.90	0.63	-0.90	0.63		-10.93	-0.86	2.62						
- At an oil price FOB of 25 US$/bbl	-5.20	-5.20	-3.67	-5.20	-1.12	0.41	-1.12	0.41		-17.59	-4.45	0.51						

(*) Assuming temperatures of 220 Centigrade

TABLE A 8.2.7 SUMMARY OF THE RESULTS OF THE ECONOMIC ANALYSIS

	UNIT	DISCOUNT RATE		
		5%	10%	15%
1. COST OF GEOTHERMAL POWER	Centimes US$ 1983			
1.1 Including the cost of exploration wells				
- At 220 C (reference)		7.63	10.66	14.47
- At 240 C		6.23	8.7	11.81
- At 260 C		5.18	7.24	9.83
- At 280 C		4.31	6.02	8.17
1.2 Excluding the cost of exploration wells				
- At 220 C (reference)		6.75	9.07	11.85
- At 240 C		5.51	7.41	9.67
- At 260 C		4.58	6.16	8.04
- At 280 C		3.81	5.12	6.69
2. COST OF DIESEL POWER	Centimes US$ 1983			
- At an oil price of 10 US$/bbl		7.11	7.86	8.73
- At an oil price of 15 US$/bbl		8.06	8.81	9.69
- At an oil price of 20 US$/bbl		8.85	9.6	10.48
- At an oil price of 25 US$/bbl		9.47	10.22	11.1
3. NET FOREIGN EXCHANGE BALANCE GEOTHERMAL - DIESEL (*)	Million US$ 1983			
3.1 Including the cost of exploration wells				
- At an oil price of 10 US$/bbl		14.9	16.57	15.64
- At an oil price of 15 US$/bbl		7.27	12.46	13.22
- At an oil price of 20 US$/bbl		-1.19	7.9	10.54
- At an oil price of 25 US$/bbl		-7.86	4.3	8.43
3.2 Excluding the cost of exploration wells				
- At an oil price of 10 US$/bbl		5.17	7.82	7.72
- At an oil price of 15 US$/bbl		-2.47	3.7	5.3
- At an oil price of 20 US$/bbl		-10.93	-0.86	2.62
- At an oil price of 25 US$/bbl		-17.59	-4.45	0.51

(*) reference 220 Centigrade

Figure A8.2.2. Cost per kWh for Diesel Generators and Geothermal Power (including cost of exploratory wells)

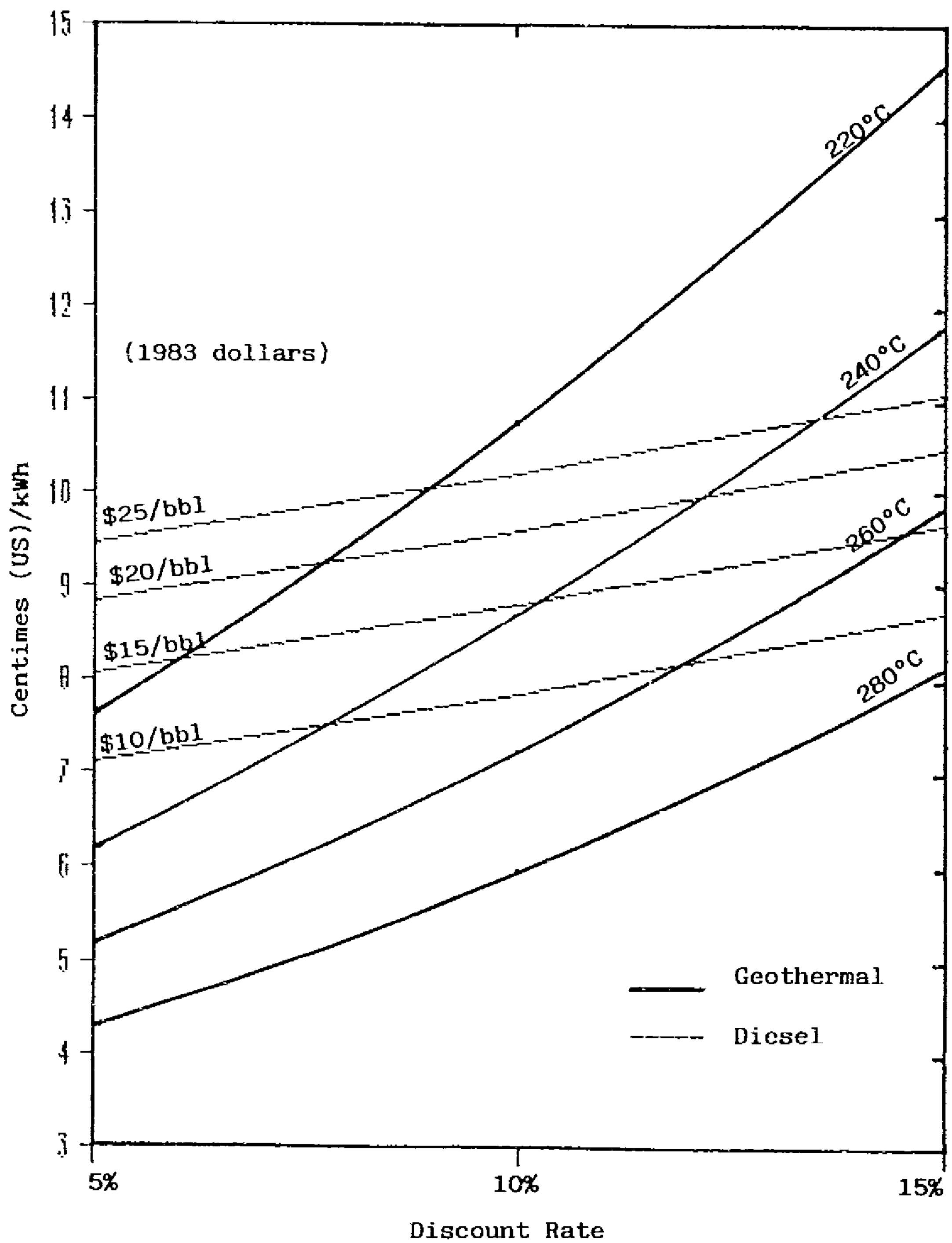
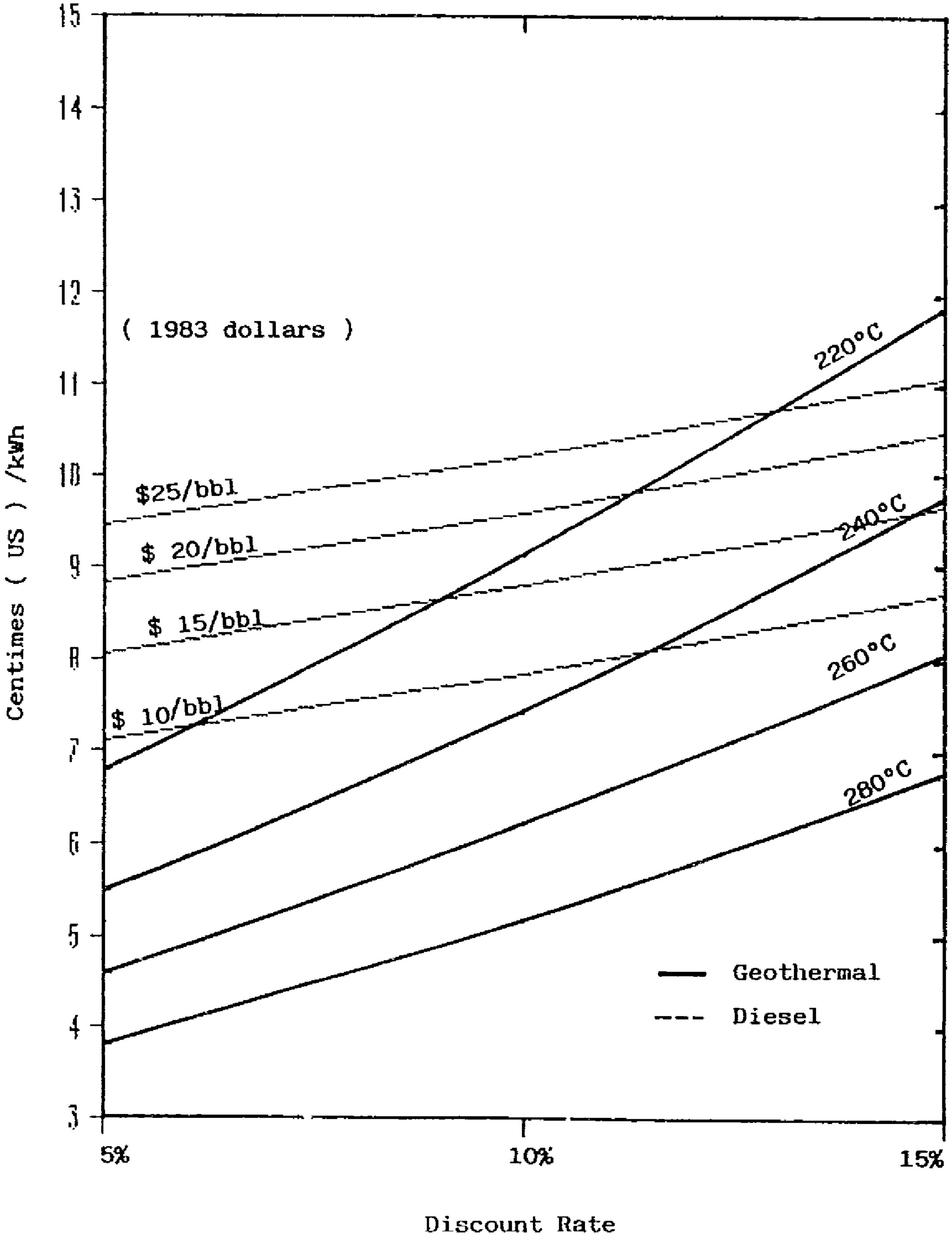


Figure A8.2.3. Cost per kWh for
Diesel Generators and Geothermal Power
(excluding cost of exploratory wells)



For the case where the cost of the exploratory wells is excluded, and assuming fluid temperatures of 220 °C, geothermal production will save foreign exchange during the period 1986-2013 if the average price of petroleum during this period remains less than US$ 15/bbl (1986 dollars).

These savings vary, in terms of present value discounted at 10%, between 0.86 and 4.45 million dollars (1983). These savings increase with both increasing geothermal fluid temperatures and the average price of petroleum.

As noted previously, taking the cost of the exploratory wells as sunk costs, and therefore excluding this cost from the calculation, is regarded as the correct manner in which to perform the economic analysis.

The threshold of $16/bbl for the average price of petroleum implies a price of $17/bbl ($ 1983) in the year 2000. According to most experts, the price of petroleum is projected to be greater than $18/bbl ($ 1983) at that time.

Thus, geothermal energy is an economic alternative for Djibouti which could lead to a much greater degree of energy independence for the country, and a reduction in the cost of the production of electricity.

A 8.2.6. Conclusions

The economic viability of the geothermal project will be determined by two factors:

- the temperature of the geothermal fluid.

- the price of petroleum.

Given the limited level of knowledge at the present time, the analysis shows that geothermal energy would be economic even if a decrease in the price of petroleum were to occur.

The thresholds of economic viability are:

- a geothermal fluid temperature of around 220 °C.

- an averge price of petroleum within the economic lifespan of the project of 16-17 US $ (1983)/bbl, i.e. a price in the year 2000 higher than 17 US $ (1983)/bbl.

These thresholds are attainable. In fact, it is likely that both the temperature of the geothermal fluid and the price of petroleum will be higher than the values indicated above.

The results of this analysis show that the geothermal project generates net savings in foreign currency over its lifespan of 0.86 - 4.45 million US $ (1983).

These economies will be greater if the temperature of the geothermal fluid is higher than 220 °C, or if the price of petroleum rises to more than 18-20 US $ (1983)/bbl by the year 2000.

ANNEX 8.3 RESULTS OF THE MEDEE-S SIMULATION

REFERENCE SCENARIO

SUMMARY OF RESULTS

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL DEMAND (TEP)	71847.000	84124.000	98716.000	116335.000
1.1	PETROLEUM PRODUCTS	48319.000	57195.000	67756.000	80473.000
1.2	ELECTRICITY	11866.000	14113.000	16781.000	20263.000
1.3	BIOMASS	11662.000	12818.000	14180.000	15599.000
1.4	OTHER RENEWABLES	0.000	0.000	0.000	0.000
2	DEMAND STRUCTURE (PERCENTAGE)				
2.1	PETROLEUM PRODUCTS	67.252	67.987	68.637	69.174
2.2	ELECTRICITY	16.516	16.777	16.999	17.417
2.3	BIOMASS	16.232	15.237	14.364	13.409
2.4	OTHER RENEWABLES	0.000	0.000	0.000	0.000
3	DEMAND BY PRODUCT (TEP)				
3.1	LPG	659.120	752.320	856.700	990.230
3.2	KEROSENE	10048.000	12752.000	15736.000	19739.000
3.3	GASOLINE	10647.000	11137.000	11738.000	12223.000
3.4	DIESEL FUEL	22413.000	27015.000	32688.000	39325.000
3.5	JET FUEL	4551.300	5537.300	6737.000	8196.000
3.6	ELECTRICITY	11866.000	14113.000	16781.000	20263.000
3.7	CHARCOAL	865.010	1094.000	1346.100	1691.300
3.8	WOOD	10797.000	11724.000	12833.000	13908.000
3.9	OTHER RENEWABLES	0.000	0.000	0.000	0.000
4	DEMAND STRUCTURE BY PRODUCT (FRACTION)				
4.1	LPG	0.917	0.894	0.868	0.851
4.2	KEROSENE	13.985	15.158	15.941	16.966
4.3	GASOLINE	14.819	13.239	11.890	10.507
4.4	DIESEL FUEL	31.196	32.113	33.113	33.803
4.5	JET FUEL	6.335	6.582	6.825	7.046
4.6	ELECTRICITY	16.516	16.777	16.999	17.417
4.7	CHARCOAL	1.204	1.300	1.364	1.454
4.8	WOOD	15.028	13.936	13.000	11.955
4.9	OTHER RENEWABLES	0.000	0.000	0.000	0.000

SUMMARY OF RESULTS: DEMAND BY SECTOR

	REFERENCE YEAR	1985	1990	1995	2000
0	TOTAL DEMAND (TEP)	71847.000	84124.000	98716.000	116335.000
1	INDUSTRY + CONSTRUCTION	3603.000	4704.300	6113.800	7913.100
2	AGRICULTURE + FISHING	203.270	239.610	279.960	327.090
2.1	TRACTORS	0.000	0.000	0.000	0.000
2.2	IRRIGATION	0.000	0.000	0.000	0.000
2.3	FISHING	116.620	133.890	151.940	171.860
2.4	FOOD PRESERVATION	86.646	105.720	128.020	155.230
3	TRANSPORTATION	28425.000	33009.000	38621.000	44888.000
3.1	AIR	4551.300	5537.300	6737.000	8196.600
3.2	BUS	4676.100	5689.100	6921.800	8421.400
3.3	AUTOMOBILES	15590.000	17393.000	19621.000	21773.000
3.4	RAILWAY	1306.000	1588.900	1933.200	2352.000
3.5	MARITIME	710.530	864.450	1051.800	1279.600
3.6	TRUCK	1591.500	1936.300	2355.800	2355.200
4	SERVICES	12546.000	14047.000	15912.000	18168.000
4.1	PUBLIC SERVICES	4543.800	5419.900	6453.700	7670.400
4.2	COMMERCE + BANKS	659.960	787.210	937.370	1114.100
4.3	HOTELS + RESTAURANTS	1284.100	1531.700	1823.900	2167.700
4.4	PUBLIC LIGHTING	150.140	218.850	320.440	472.150
4.5	WATER PUMPING	408.640	589.850	877.510	1244.700
4.6	FRENCH ARMY	5499.000	5499.000	5499.000	5499.000
5	RESIDENTIAL	27070.000	32124.000	37789.000	45039.000
5.1	COOKING	19702.000	23190.000	27178.000	32194.000
5.2	LIGHTING	1329.200	1540.500	1738.200	1956.700
5.3	APPLIANCES	5173.700	6299.300	7526.700	9196.100

DEMAND STRUCTURE BY SECTOR (FRACTION)

		1985	1990	1995	2000
1.0	INDUSTRY + CONSTRUCTION	0.050	0.056	0.062	0.068
2.0	AGRICULTURE + FISHING	0.003	0.003	0.003	0.003
3.0	TRANSPORTATION	0.396	0.392	0.391	0.386
4.0	SERVICES	0.175	0.167	0.161	0.156
5.0	RESIDENTIAL	0.377	0.382	0.383	0.387

FINAL DEMAND FOR ELECTRICITY (MWh)

	REFERENCE YEAR	1985	1990	1995	2000
	TOTAL DEMAND (MWh)	137980.000	164110.000	195120.000	235616.000
1	INDUSTRY	5072.500	6623.000	8607.400	11141.000
2	AGRICULTURE	1007.500	1229.300	1488.600	1805.000
2.1	IRRIGATION	0.000	0.000	0.000	0.000
2.2	FOOD PRESERVATION	1007.500	1229.300	1488.600	1805.000
3	SERVICES	67326.000	77255.000	90000.000	105700.000
3.1	ADMINISTRATION	22955.000	27381.000	32604.000	38750.000
3.2	COMMERCE	7674.000	9153.700	10900.000	12954.000
3.3	HOTELS, RESTAURANTS	7150.300	8529.000	10156.000	12070.000
3.4	PUBLIC LIGHTING	1745.800	2544.700	3726.100	5490.200
3.5	WATER PUMPING	4266.000	6112.000	9080.300	12896.000
3.6	FRENCH ARMY	23535.000	23535.000	23535.000	23535.000
4	HOUSEHOLDS	64572.000	79000.000	95026.000	116970.000
4.1	LIGHTING	4412.700	5752.500	7506.600	10037.000
4.2	VENTILATION	7515.700	9432.200	11522.000	14404.000
4.3	AIR CONDITIONING	30924.000	36442.000	42465.000	50477.000
4.4	REFRIGERATION	19225.000	24355.000	29909.000	37599.000
4.5	TELEVISION + OTHER	2462.100	3018.200	3624.200	4451.800
4.6	COOKING	0.000	0.000	0.000	0.000
	DEMAND STRUCTURE (FRACTION)				
1.0	INDUSTRY	0.037	0.040	0.044	0.047
2.0	AGRICULTURE	0.007	0.007	0.008	0.008
3.0	SERVICES	0.488	0.471	0.461	0.449
4.0	HOUSEHOLDS	0.468	0.481	0.487	0.496

MACROECONOMIC VARIABLES

	REFERENCE YEAR	1985	1990	1995	2000
1	GROSS DOMESTIC PRODUCT (MFD)	60234.000	73283.000	89161.000	108480.000
	1.1 AGRICULTURE,LIVESTOCK,FISHING	2710.500	3810.700	5349.700	7593.500
	1.2 INDUSTRY AND MANUFACTURING	4939.200	6448.900	8381.100	10848.000
	1.3 WATER AND ELECTRICITY	1927.500	2345.100	2853.200	3471.300
	1.4 BUILDINGS AND PUBLIC WORKS	4517.600	5642.800	7043.700	8678.200
	1.5 SERVICES	46139.000	55036.000	65533.000	77887.000
2	STRUCTURE OF GDP (FRACTION)				
	2.1 AGRICULTURE,LIVESTOCK,FISHING	0.045	0.052	0.600	0.070
	2.2 INDUSTRY AND MANUFACTURING	0.082	0.088	0.094	0.100
	2.3 WATER AND ELECTRICITY	0.032	0.032	0.032	0.032
	2.4 BUILDINGS AND PUBLIC WORKS	0.075	0.077	0.079	0.080
	2.5 SERVICES	0.766	0.751	0.735	0.718

INDUSTRIAL SECTOR: ENERGY DEMAND

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL (TEP)	3063.000	4704.300	6113.800	7913.100
	1.1 DIESEL FUEL	3166.800	4134.700	5373.500	6955.000
	1.2 FUEL OIL	0.000	0.000	0.000	0.000
	1.3 ELECTRICITY	436.240	569.580	740.240	958.100
	1.4 GEOTHERMAL	0.000	0.000	0.000	0.000
	1.5 SOLAR ENERGY	0.000	0.000	0.000	0.000
2	DEMAND STRUCTURE (FRACTION)				
	2.1 DIESEL FUEL	0.879	0.879	0.879	0.879
	2.2 FUEL OIL	0.000	0.000	0.000	0.000
	2.3 ELECTRICITY	0.121	0.121	0.121	0.121
	2.4 GEOTHERMAL	0.000	0.000	0.000	0.000
	2.5 SOLAR ENERGY	0.000	0.000	0.000	0.000
3	ELECTRICITY DEMAND (MWH)	5072.500	6623.000	8607.400	11141.000

RESIDENTIAL SECTOR: TOTAL ENERGY DEMAND

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL DEMAND (TEP)	27070.000	32124.000	37789.000	45039.000
1.1	LPG	419.150	491.580	571.400	676.030
1.2	KEROSENE	9435.300	12021.000	14866.000	18704.000
1.3	ELECTRICITY	5553.200	6794.000	8172.300	10059.000
1.4	WOOD	10797.000	11724.000	12833.000	13908.000
1.5	CHARCOAL	865.010	1094.000	1346.100	1691.300
2	DEMAND STRUCTURE (FRACTION)				
2.1	LPG	0.015	0.015	0.015	0.015
2.2	KEROSENE	0.349	0.374	0.393	0.415
2.3	ELECTRICITY	0.205	0.211	0.216	0.223
2.4	WOOD	0.399	0.365	0.340	0.309
2.5	CHARCOAL	0.032	0.034	0.036	0.038
3	DEMAND BY END-USE (TEP)				
3.1	COOKING	19702.000	23190.000	27178.000	32194.000
	*LPG	419.190	491.580	571.400	676.030
	*KEROSENE	8485.600	10975.000	13774.000	17610.000
	*ELECTRICITY	0.000	0.000	0.000	0.000
	*WOOD	10797.000	11724.000	12833.000	13908.000
3.2	LIGHTING	1329.200	1540.700	1738.200	1956.700
	*KEROSENE	949.690	1046.000	1092.700	1093.500
	*ELECTRICITY	379.500	494.710	645.570	863.200
3.3	APPLIANCES	5173.700	6299.300	7526.700	9196.100
	*VENTILATION	646.350	811.170	990.850	1238.800
	*AIR CONDITIONING	2659.500	3134.000	3652.000	4341.000
	*REFRIGERATION	1656.200	2094.500	2572.200	3233.500
	*TELEVISION + OTHER	211.740	259.560	311.680	382.860
3.4	OTHER (CHARCOAL)	865.010	1094.000	1346.100	1691.300

RESIDENTIAL SECTOR: ELECTRICITY DEMAND

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL (MWh)	64572.000	79000.000	95026.000	116970.000
1.1	LIGHTING	4412.700	5752.500	7506.600	10037.000
1.2	VENTILATION	7515.700	9432.200	11522.000	14404.000
1.3	AIR CONDITIONING	30924.000	36442.000	42465.000	50477.000
1.4	REFRIGERATION	19258.000	24355.000	29909.000	37599.000
1.5	TELEVISION + OTHER	2462.100	3018.200	3624.200	4451.800
1.6	COOKING	0.000	0.000	0.000	0.000
2	DEMAND STRUCTURE BY END-USE (FRACTION)				
2.1	LIGHTING	0.068	0.073	0.079	0.086
2.2	VENTILATION	0.116	0.119	0.121	0.123
2.3	AIR CONDITIONING	0.479	0.461	0.447	0.432
2.4	REFRIGERATION	0.298	0.308	0.315	0.321
2.5	TELEVISION + OTHER	0.038	0.038	0.038	0.038
2.6	COOKING	0.000	0.000	0.000	0.000
3	HOUSEHOLDS WITH ELECTRICTY (FRACTION)				
3.1	DJIBOUTI VILLE				
	-LOW REVENUE	0.540	0.592	0.675	0.767
	-AVERAGE REVENUE	1.000	1.000	1.000	1.000
	-HIGH REVENUE	1.000	1.000	1.000	1.000
	-EXPATRIATES	1.000	1.000	1.000	1.000
3.2	DISTRICT CENTRES	0.150	0.261	0.394	0.542
3.3	RURAL AREAS AND OTHERS	0.001	0.002	0.003	0.004

DEMOGRAPHIC VARIABLES

	REFERENCE YEAR	1985	1990	1995	2000
1	POPULATION (THOUSANDS)	430.000	498.000	580.000	670.000
	1.1 DJIBOUTI VILLE	249.400	298.800	359.600	435.500
	1.2 DISTRICT CENTRES + OTHERS	180.600	199.200	220.400	234.500
	FRACTION URBANIZED	0.580	0.600	0.620	0.650
2	NUMBER OF HOUSEHOLDS (THOUS.)	53.948	66.092	79.866	97.894
	2.1 DJIBOUTI VILLE	31.923	41.192	51.243	65.325
	-LOW REVENUE	22.921	30.194	38.074	49.190
	-AVERAGE REVENUE	5.267	6.797	8.455	10.779
	-HIGH REVENUE	1.660	2.142	2.665	3.397
	-EXPATRIATES	2.075	2.060	2.050	1.960
	2.2 DISTRICT CENTRES	10.285	11.628	13.367	15.210
	2.3 RURAL AND OTHER	11.739	13.272	15.256	17.360
3	HOUSEHOLD STRUCTURE (FRACTION)				
	3.1 DJIBOUTI VILLE				
	-LOW REVENUE	0.718	0.733	0.743	0.753
	-AVERAGE REVENUE	0.165	0.165	0.165	0.165
	-HIGH REVENUE	0.052	0.052	0.052	0.052
	-EXPATRIATES	0.065	0.050	0.040	0.030
	3.2 DISTRICTS AND OTHERS				
	-DISTRICT CENTRES	0.467	0.467	0.467	0.467
	-RURAL AND OTHERS	0.533	0.533	0.533	0.533

HOUSEHOLD ENERGY USED FOR COOKING

REFERENCE YEAR	1985	1990	1995	2000
1 DJIBOUTI VILLE (NUMBER OF HOUSEHOLDS IN THOUSANDS)				
1.1 LOW REVENUE	22.921	30.194	38.074	49.190
-LPG	0.000	0.000	0.000	0.000
-KEROSENE	21.546	28.684	36.551	47.714
-ELECTRICITY	0.000	0.000	0.000	0.000
-WOOD	1.375	1.510	1.523	1.476
1.2 AVERAGE REVENUE	5.267	6.797	8.455	10.779
-LPG	0.632	0.816	1.015	1.293
-KEROSENE	4.635	5.981	7.440	9.485
-ELECTRICITY	0.000	0.000	0.000	0.000
-WOOD	0.000	0.000	0.000	0.000
1.3 HIGH REVENUE	1.660	2.142	2.665	3.397
-LPG	0.780	1.007	1.252	1.597
-KEROSENE	0.880	1.135	1.412	1.800
-ELECTRICITY	0.000	0.000	0.000	0.000
-WOOD	0.000	0.000	0.000	0.000
1.4 EXPATRIATES	2.075	2.060	2.050	1.960
-LPG	2.075	2.060	2.050	1.960
-KEROSENE	0.000	0.000	0.000	0.000
-ELECTRICITY	0.000	0.000	0.000	0.000
-WOOD	0.000	0.000	0.000	0.000
1.5 TOTAL DJIBOUTI VILLE				
-LPG	3.487	3.882	4.314	4.850
-KEROSENE	27.061	35.800	45.403	59.000
-ELECTRICITY	0.000	0.000	0.000	0.000
-WOOD	1.375	1.510	1.523	1.476
2 DISTRICT CENTRES	10.285	11.628	13.367	15.210
-LPG	0.134	0.156	0.184	0.216
-KEROSENE	6.552	7.635	9.039	10.583
-WOOD	3.600	3.837	4.144	4.411
3 RURAL AND OTHERS	11.739	13.272	15.256	17.360
-LPG	0.000	0.000	0.000	0.000
-KEROSENE	1.174	1.526	1.983	2.517
-WOOD	10.565	11.745	13.273	14.842

SERVICE SECTOR: TOTAL ENERGY DEMAND

REFERENCE YEAR	1985	1990	1995	2000
1 TOTAL DEMAND (TEP)	12546.000	14047.000	15912.000	18168.000
1.1 LPG	239.930	260.740	285.300	314.200
1.2 KEROSENE	612.650	730.770	870.160	1034.200
1.3 GASOLINE	3012.400	3136.300	3282.500	3454.500
1.4 DIESEL FUEL	2890.600	3274.800	3734.000	4275.200
1.5 ELECTRICITY	5790.000	6643.900	7740.000	9089.900
1.6 SOLAR AND WIND ENERGY	0.000	0.000	0.000	0.000
2 DEMAND STRUCTURE (FRACTION)				
2.1 LPG	0.019	0.019	0.018	0.017
2.2 KEROSENE	0.049	0.052	0.055	0.057
2.3 GASOLINE	0.240	0.223	0.206	0.190
2.4 DIESEL FUEL	0.230	0.233	0.235	0.235
2.5 ELECTRICITY	0.462	0.473	0.486	0.500
2.6 SOLAR AND WIND ENERGY	0.000	0.000	0.000	0.000
3 DEMAND BY SECTOR (TEP)				
3.1 ADMINISTRATION AND PUBLIC SERVICES	4543.800	5419.900	6453.700	7670.400
3.2 COMMERCE, BANKS, AND INSURANCE	659.960	787.210	937.370	1114.100
3.3 HOTELS, BARS, AND RESTAURANTS	1284.100	1531.700	1823.900	2167.700
3.4 PUBLIC LIGHTING	150.140	218.850	320.440	472.150
3.5 WATER PUMPING	408.640	589.850	877.510	1244.700
-ELECTRICITY	366.880	525.630	780.910	1109.100
-DIESEL FUEL	41.765	64.218	96.601	135.600
-SOLAR AND WIND ENERGY	0.000	0.000	0.000	0.000
3.6 FRENCH ARMY	5499.000	5499.000	5499.000	5499.000
-LPG	132.000	132.000	132.000	132.000
-KEROSENE	0.000	0.000	0.000	0.000
-GASOLINE	2370.000	2370.000	2370.000	2370.000
-DIESEL FUEL	973.000	973.000	973.000	973.000
-ELECTRICITY	2024.000	2024.000	2024.000	2024.000

SERVICE SECTOR: ELECTRICITY DEMAND

REFERENCE YEAR	1985	1990	1995	2000
TOTAL DEMAND (MWh)	67326.000	77255.000	90000.000	105700.000
1.1 ADMINISTRATION AND PUBLIC SERVICES	22955.000	27381.000	32604.000	38750.000
1.2 COMMERCE, BANKS, AND INSURANCE	7674.000	9153.700	10900.000	12954.000
1.3 HOTELS, BARS, AND RESTAURANTS	7150.300	8529.000	10156.000	12070.000
1.4 PUBLIC LIGHTING	1745.800	2544.700	3726.100	5490.200
1.5 WATER PUMPING	4266.000	6112.000	9080.300	12896.000
1.6 FRENCH ARMY	23535.000	23535.000	23535.000	23535.000

TRANSPORTATION SECTOR: LOCAL MARKET

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL DEMAND (TEP)	28425.000	33009.000	38621.000	44888.000
1.1	GASOLINE	7634.700	8000.600	8455.100	8768.600
1.2	DIESEL FUEL	16239.000	19472.000	23429.000	27923.000
1.3	JET FUEL	4551.300	5537.300	6737.000	8196.600
2	DEMAND STRUCTURE (FRACTION)				
2.1	GASOLINE	0.269	0.242	0.219	0.195
2.2	DIESEL FUEL	0.571	0.590	0.607	0.622
2.3	JET FUEL	0.160	0.168	0.174	0.183
3	DEMAND BY MODE (TEP)	28425.000	33009.000	38621.000	44888.000
3.1	AIR	4551.300	5537.300	6737.000	8196.600
3.2	BUS	4676.100	5689.100	6921.800	8421.400
3.3	INDIVIDUAL	15590.000	17393.000	19621.000	21773.000
3.4	RAILWAY	1306.000	1583.900	1933.200	2352.000
3.5	MARITIME	710.530	864.450	1051.800	1279.600
3.6	TRUCK	1591.500	1936.300	2355.800	2866.200
4	DEMAND STRUCTURE BY MODE OF TRANSPORT (FRACTION)				
4.1	AIR	0.160	0.168	0.174	0.183
4.2	BUS	0.165	0.172	0.179	0.188
4.3	INDIVIDUAL	0.548	0.527	0.508	0.485
4.4	RAILWAY	0.046	0.048	0.050	0.052
4.5	MARITIME	0.025	0.026	0.027	0.029
4.6	TRUCK	0.056	0.059	0.061	0.064

TRANSPORTATION SECTOR: TOTAL ENERGY DEMAND

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL DEMAND (TEP)	154790.000	167000.000	181860.000	199940.000
1.2	AIRPORT	57608.000	57608.000	57608.000	57608.000
1.3	PORT (BUNKERING)	97182.000	109390.000	124250.000	142230.000

TRANSPORTATION SECTOR VARIABLES

	REFERENCE YEAR	1985	1990	1995	2000
1	PASSENGER TRAFFIC (MILLION PASSENGERS X KM)	1809.900	2147.100	2559.500	3044.600
1.1	AIR	32.500	39.541	48.103	58.531
1.2	PUBLIC TRANSPORT	1305.800	1588.600	1932.900	2351.600
	-RAILWAY	277.000	337.000	410.000	498.000
	-ROAD	1027.400	1250.000	1520.800	1850.300
	-MARITIME	1.350	1.643	1.998	2.431
1.3	AUTOMOBILES	470.680	518.900	578.510	634.500
2	PUBLIC TRANSPORT				
2.1	FLEET OF VEHICLES	521.000	633.000	771.000	938.000
2.2	TRAFFIC (MILLION PASSENGERS X KM)	171240.000	208330.000	253470.000	308390.000
3	AUTOMOBILES				
3.1	FLEET OF VEHICLES (THOUS.)	11.622	12.812	14.284	15.667
4	TRANSPORTATION OF GOODS (MILLION TONNES X KM)				
4.1	TRAFFIC (TOTAL)	139.680	169.940	206.760	251.550
	-ROAD	6.579	8.004	9.738	11.848
	-RAIL	133.100	161.930	197.020	239.710
4.2	FLEET OF VEHICLES	430.000	523.000	636.000	774.000

AGRICULTURAL AND FISHING SECTOR

REFERENCE YEAR	1985	1990	1995	2000
1 DEMAND BY ENERGY TYPE (TEP)	203.270	239.610	279.960	327.090
1.1 DIESEL FUEL AND GASOLINE	116.620	133.890	151.940	171.860
1.2 ELECTRICITY	86.646	105.720	128.020	155.230
1.3 SOLAR AND WIND	0.000	0.000	0.000	0.000
2 DEMAND STRUCTURE (FRACTION)				
2.1 DIESEL FUEL AND GASOLINE	0.574	0.559	0.543	0.525
2.2 ELECTRICITY	0.426	0.441	0.457	0.475
2.3 SOLAR AND WIND	0.000	0.000	0.000	0.000
3 DEMAND BY ENERGY USE (TEP)				
3.1 TRACTORS	0.000	0.000	0.000	0.000
-DIESEL FUEL	0.000	0.000	0.000	0.000
3.2 IRRIGATION	0.000	0.000	0.000	0.000
-DIESEL FUEL	0.000	0.000	0.000	0.000
-ELECTRICITY	0.000	0.000	0.000	0.000
-SOLAR AND WIND	0.000	0.000	0.000	0.000
3.3 FISHING	116.620	133.890	151.940	171.860
-DIESEL FUEL	116.620	133.890	151.940	171.860
3.4 FOOD PRESERVATION	86.646	105.720	128.020	155.230
-DIESEL FUEL	0.000	0.000	0.000	0.000
-ELECTRICITY	86.646	105.720	128.020	155.230
-SOLAR AND WIND	0.000	0.000	0.000	0.000
4 DEMAND STRUCTURE BY END-USE (FRACTION)				
4.1 TRACTORS	0.000	0.000	0.000	0.000
4.2 IRRIGATION	0.000	0.000	0.000	0.000
4.3 FISHING	0.574	0.559	0.543	0.525
4.4 FOOD PRESERVATION	0.426	0.441	0.457	0.475

ANNEX 8.4 RESULTS OF THE MEDEE-S SIMULATION

GROWTH SCENARIO

SUMMARY OF RESULTS

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL DEMAND (TEP)	71847.000	87702.000	109004.000	140574.000
1.1	PETROLEUM PRODUCTS	48319.000	60316.000	76726.000	99816.000
1.2	ELECTRICITY	11866.000	14828.000	19470.000	26655.000
1.3	BIOMASS	11662.000	12109.000	11082.000	9712.000
1.4	OTHER RENEWABLES	0.000	449.000	1726.000	4391.000
2	DEMAND STRUCTURE (PERCENTAGE)				
2.1	PETROLEUM PRODUCTS	67.253	68.774	70.388	71.006
2.2	ELECTRICITY	16.516	16.907	17.862	18.962
2.3	BIOMASS	16.232	13.807	10.167	6.909
2.4	OTHER RENEWABLES	0.000	0.512	1.583	3.124
3	DEMAND BY PRODUCT (TEP)				
3.1	LPG	659.120	916.380	1379.200	2346.500
3.2	KEROSENE	10048.000	12867.000	16795.000	21893.000
3.3	GASOLINE	10647.000	11758.000	13270.000	15815.000
3.4	DIESEL FUEL	22413.000	28966.000	37868.000	50300.000
3.5	JET FUEL	4551.300	5808.800	7413.600	9461.800
3.6	ELECTRICITY	11866.000	14828.000	19470.000	26655.000
3.7	CHARCOAL	865.010	1072.700	1259.400	1561.900
3.8	WOOD	10797.000	11036.000	9822.600	8150.200
3.9	OTHER RENEWABLES	0.000	449.000	1726.000	4391.000
4	DEMAND STRUCTURE BY PRODUCT (FRACTION)				
4.1	LPG	0.917	1.045	1.266	1.670
4.2	KEROSENE	13.985	14.675	15.415	15.585
4.3	GASOLINE	14.819	13.410	12.180	11.258
4.4	DIESEL FUEL	31.196	33.036	34.756	35.807
4.5	JET FUEL	6.335	6.625	6.804	6.736
4.6	ELECTRICITY	16.516	16.912	17.870	18.975
4.7	CHARCOAL	1.204	1.223	1.156	1.112
4.8	WOOD	15.028	12.587	9.015	5.802
4.9	OTHER RENEWABLES	0.000	0.000	0.458	1.404

SUMMARY OF RESULTS: DEMAND BY SECTOR

	REFERENCE YEAR	1985	1990	1995	2000
0	TOTAL DEMAND (TEP)	71847.000	87679.000	108950.000	140470.000
1	INDUSTRY + CONSTRUCTION	3603.000	5007.200	7063.300	10247.000
2	AGRICULTURE + FISHING	203.270	279.690	342.750	430.000
2.1	TRACTORS	0.000	0.000	0.000	0.000
2.2	IRRIGATION	0.000	0.000	0.000	0.000
2.3	FISHING	116.620	156.290	186.020	225.930
2.4	FOOD PRESERVATION	86.646	123.410	156.740	204.070
3	TRANSPORTATION	28425.000	35561.000	45819.000	61521.000
3.1	AIR	4551.300	5808.800	7413.600	9461.800
3.2	BUS	4676.100	6343.400	9057.600	12884.000
3.3	AUTOMOBILES	15590.000	18697.000	23074.000	30712.000
3.4	RAILWAY	1306.000	1666.800	2127.300	2715.100
3.5	MARITIME	710.530	905.840	1157.400	1477.100
3.6	TRUCK	1591.500	2148.500	2989.800	4271.800
4	SERVICES	12546.000	14855.000	17846.000	21325.000
4.1	PUBLIC SERVICES	4543.800	5846.800	7289.900	8794.200
4.2	COMMERCE + BANKS	659.960	845.190	1112.100	1404.400
4.3	HOTELS + RESTAURANTS	1284.100	1780.800	2574.400	3574.200
4.4	PUBLIC LIGHTING	150.140	237.230	386.750	628.8[illegible]0
4.5	WATER PUMPING	408.640	604.670	942.740	1382.800
4.6	FRENCH ARMY	5499.000	5540.000	5540.000	5540.000
5	RESIDENTIAL	27070.000	32000.000	37932.000	47052.000
5.1	COOKING	19702.000	22774.000	25847.000	30327.000
5.2	LIGHTING	1329.200	1547.000	1747.500	2014.800
5.3	APPLIANCES	5173.700	6606.200	9077.900	13148.000

DEMAND STRUCTURE BY SECTOR (FRACTION)

1	INDUSTRY + CONSTRUCTION	0.050	0.057	0.065	0.073
2	AGRICULTURE + FISHING	0.003	0.003	0.003	0.003
3	TRANSPORTATION	0.396	0.406	0.421	0.438
4	SERVICES	0.175	0.169	0.164	0.152
5	RESIDENTIAL	0.377	0.365	0.348	0.355

FINAL DEMAND FOR ELECTRICITY (MWh)

	REFERENCE YEAR	1985	1990	1995	2000
	TOTAL DEMAND (MWh)	137980.000	172420.000	226390.000	309940.000
1	INDUSTRY	5072.500	8034.100	13345.000	24000.000
2	AGRICULTURE	1007.500	1435.000	1822.500	2372.900
2.1	IRRIGATION	0.000	0.000	0.000	0.000
2.2	FOOD PRESERVATION	1007.500	1435.000	1822.500	2372.900
3	SERVICES	67326.000	79734.000	95435.000	113420.000
3.1	ADMINISTRATION	22955.000	27594.000	31635.000	34702.000
3.2	COMMERCE	7674.000	9827.800	12932.000	16330.000
3.3	HOTELS, RESTAURANTS	7150.300	9413.000	12591.000	16487.000
3.4	PUBLIC LIGHTING	1745.800	2758.500	4497.100	7312.600
3.5	WATER PUMPING	4266.000	6302.800	9942.100	14751.000
3.6	FRENCH ARMY	23535.000	23837.000	23837.000	23837.000
4	HOUSEHOLDS	64572.000	83216.900	11587.500	170147.100
4.1	LIGHTING	4412.700	6136.300	9652.200	16115.000
4.2	VENTILATION	7515.700	10220.000	14695.000	22133.000
4.3	AIR CONDITIONING	30924.000	36946.000	48088.000	66177.000
4.4	REFRIGERATION	19258.000	26474.000	38355.000	58094.000
4.5	TELEVISION + OTHER	2462.100	3175.700	4419.600	6476.300
4.6	COOKING	0.000	264.[illegible]00	577.700	1151.800
	DEMAND STRUCTURE (FRACTION)				
1	INDUSTRY	0.037	0.047	0.059	0.077
2	AGRICULTURE	0.007	0.008	0.008	0.008
3	SERVICES	0.488	0.462	0.422	0.366
4	HOUSEHOLDS	0.468	0.483	0.051	0.549

MACROECONOMIC VARIABLES

	REFERENCE YEAR	1985	1990	1995	2000
1	GROSS DOMESTIC PRODUCT (MFD)	60234.000	76876.000	98115.000	125220.000
1.1	AGRICULTURE,LIVESTOCK,FISHING	2710.500	4512.600	6868.000	10644.000
1.2	INDUSTRY MANUFACTURING	4939.200	6918.800	10302.000	16279.000
1.3	WATER AND ELECTRICITY	1927.500	2690.700	4415.200	7513.000
1.4	BUILDINGS AND PUBLIC WORKS	4517.600	5996.300	8143.500	11270.000
1.5	SERVICES	46139.000	56658.000	68386.000	79516.000
2	STRUCTURE OF GDP (FRACTION)				
2.1	AGRICULTURE,LIVESTOCK,FISHING	0.045	0.060	0.070	0.085
2.2	INDUSTRY MANUFACTURING	0.082	0.090	0.105	0.130
2.3	WATER AND ELECTRICITY	0.032	0.035	0.045	0.060
2.4	BUILDINGS AND PUBLIC WORKS	0.075	0.078	0.083	0.090
2.5	SERVICES	0.766	0.737	0.697	0.635

INDUSTRIAL SECTOR : ENERGY DEMAND

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL (TEP)	3603.000	5007.200	7063.300	10247.000
1.1	DIESEL FUEL	3166.800	4316.200	5416.200	6210.100
1.2	FUEL OIL	0.000	0.000	0.000	0.000
1.3	ELECTRICITY	436.240	690.930	1147.700	2064.000
1.4	GEOTHERMAL	0.000	0.000	356.680	1409.000
1.5	SOLAR ENERGY	0.000	0.000	142.670	563.610
2	DEMAND STRACTURE (FRACTION)				
2.1	DIESEL FUEL	0.879	0.862	0.767	0.606
2.2	FUEL OIL	0.000	0.000	0.000	0.000
2.3	ELECTRICITY	0.121	0.138	0.162	0.201
2.4	GEOTHERMAL	0.000	0.000	0.050	0.138
2.5	SOLAR ENERGY	0.000	0.000	0.020	0.055
3	ELECTRICITY DEMAND (MWh)	5072.500	8034.100	13345.000	24000.000

RESIDENTIAL SECTOR: TOTAL ENERGY DEMAND

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL DEMAND (TEP)	27070.000	32000.000	37932.000	47052.000
1.1	LPG	419.190	603.620	974.610	1763.000
1.2	KEROSENE	9435.300	12130.000	15917.000	20944.000
1.3	ELECTRICITY	5553.200	7157.000	9957.800	14633.000
1.4	WOOD	10797.000	11036.000	9822.600	8150.200
1.5	CHARCOAL	865.010	1072.700	1259.400	1561.900
2	DEMAND STRUCTURE (FRACTION)				
2.1	LPG	0.015	0.019	0.026	0.037
2.2	KEROSENE	0.349	0.379	0.420	0.445
2.3	ELECTRICITY	0.205	0.224	0.263	0.311
2.4	WOOD	0.399	0.345	0.259	0.173
2.5	CHARCOAL	0.032	0.034	0.033	0.033
3	DEMAND BY END-USE (TEP)				
3.1	COOKING	19702.000	22774.000	25847.000	30327.000
	*LPG	419.190	603.620	974.610	1763.000
	*KEROSENE	8485.600	11111.000	15000.000	20315.000
	*ELECTRICITY	0.000	23.136	49.746	99.485
	*WOOD	10797.000	11036.000	9822.600	8150.200
3.2	ELECTRICITY	1329.200	1547.000	1747.500	2014.800
	*KEROSENE	949.690	1019.300	917.370	628.950
	*ELECTRICITY	379.500	527.730	830.090	1385.900
3.3	APPLIANCES	5173.700	6606.200	9077.900	13148.000
	*VENTILATION	646.350	878.940	1263.800	1903.400
	*AIRCONDITIONING	2659.500	3177.400	4135.000	5691.200
	*REFRIGERATION	1656.200	2276.700	3298.500	4996.100
	*TELEVISION + OTHER	211.740	273.110	380.080	556.960
3.4	OTHER (CHARCOAL)	865.010	1072.700	1259.400	1561.900

RESIDENTIAL SECTOR: ELECTRICITY DEMAND

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL (MWh)	64572.000	83216.900	115787.500	170147.100
	1.1 LIGHTING	4412.700	6136.300	9652.200	16115.000
	1.2 VENTILATION	7515.700	10220.000	14695.000	22133.000
	1.3 AIR CONDITIONING	30924.000	36946.000	48088.000	66177.000
	1.4 REFRIGERATION	19258.000	26474.000	38355.000	58094.000
	1.5 TELEVISION + OTHER	2462.100	3175.700	4419.600	6476.300
	1.6 COOKING	0.000	264.900	577.700	1151.800
2	DEMAND STRUCTURE BY END-USE (FRACTION)				
	2.1 LIGHTING	0.068	0.074	0.083	0.095
	2.2 VENTILATION	0.116	0.123	0.127	0.130
	2.3 AIR CONDITIONING	0.479	0.444	0.415	0.389
	2.4 REFRIGERATION	0.298	0.318	0.331	0.341
	2.5 TELEVISION + OTHER	0.038	0.038	0.038	0.038
	2.6 COOKING	0.000	0.003	0.005	0.007
3	HOUSEHOLDS WITH ELECTRICITY (FRACTION)				
	3.1 DJIBOUTI VILLE				
	-LOW REVENUE	0.540	0.594	0.750	0.930
	-AVERAGE REVENUE	1.000	1.000	1.000	1.000
	-HIGH REVENUE	1.000	1.000	1.000	1.000
	-EXPATRIATES	1.000	1.000	1.000	1.000
	3.2 DISTRICT CENTRES	0.150	0.256	0.336	0.442
	3.3 RURAL AREAS AND OTHERS	0.001	0.002	0.004	0.008

DEMOGRAPHIC VARIABLES

	REFERENCE YEAR	1985	1990	1995	2000
1	POPULATION	430,000	498,000	580,000	670,000
	1.1 DJIBOUTI VILLE	249,400	308,760	394,400	502,500
	1.2 DISTRICT CENTES + OTHERS	180,600	189,240	185,600	167,500
	FRACTION URBANIZED	0.580	0.620	0.680	0.750
2	NUMBER OF HOUSEHOLDS	53,948	66,220	82,386	106,000
	2.1 DJIBOUTI VILLE	31,923	42,565	57,965	82,075
	-LOW REVENUE	22,921	31,243	42,025	58,273
	-AVERAGE REVENUE	5,267	7,151	11,129	18,139
	-HIGH REVENUE	1,660	2,128	2,782	3,693
	-EXPATRIATES	2,075	2,043	2,029	1,970
	2.2 DISTRICTS CENTRES	10,285	11,827	14,653	16,750
	2.3 RURAL AND OTHER	11,739	11,827	9,768	7,179
3	HOUSEHOLD STRUCTURE (FRACTION)				
	3.1 DJIBOUTI VILLE				
	-LOW REVENUE	0.718	0.734	0.725	0.710
	-AVERAGE REVENUE	0.165	0.168	0.192	0.221
	-HIGH REVENUE	0.052	0.050	0.048	0.045
	-EXPATRIATES	0.065	0.048	0.035	0.024
	3.2 DISTRICTS AND OTHERS				
	-DISTRICT CENTRES	0.467	0.500	0.600	0.700
	-RURAL AND OTHERS	0.533	0.500	0.400	0.300

HOUSEHOLD ENERGY USED FOR COOKING

	REFERENCE YEAR	1985	1990	1995	2000
1	DJIBOUTI VILLE (NUMBER OF HOUSEHOLDS IN THOUSANDS)				
1.1	LOW REVENUE	22.921	31.243	42.025	58.273
	-LPG	0.000	0.000	0.000	0.000
	-KEROSENE	21.546	29.680	40.554	57.108
	-ELECTRICITY	0.000	0.000	0.000	0.000
	-WOOD	1.375	1.562	1.471	1.166
1.2	AVERAGE REVENUE	5.267	7.151	11.129	18.139
	-LPG	0.632	1.287	2.782	6.348
	-KEROSENE	4.635	5.864	8.347	11.790
	-ELECTRICITY	0.000	0.000	0.000	0.000
	-WOOD	0.000	0.000	0.000	0.000
1.3	HIGH REVENUE	1.660	2.128	2.782	3.693
	-LPG	0.780	1.011	1.367	1.884
	-KEROSENE	0.880	1.011	1.165	1.256
	-ELECTRICITY	0.000	0.106	0.250	0.554
	-WOOD	0.000	0.000	0.000	0.000
1.4	EXPATRIATES	2.075	2.043	2.029	1.970
	-LPG	2.075	1.880	1.724	1.477
	-KEROSENE	0.000	0.000	0.000	0.000
	-ELECTRICITY	0.000	0.163	0.304	0.492
	-WOOD	0.000	0.000	0.000	0.000
1.5	TOTAL DJIBOUTI VILLE				
	-LPG	3.487	4.178	5.874	9.710
	-KEROSENE	27.061	36.555	50.065	70.154
	-ELECTRICITY	0.000	0.270	0.555	1.046
	-WOOD	1.375	1.562	1.471	1.166
2	DISTRICT CENTRES	10.285	11.827	14.653	16.750
	-LPG	0.134	0.396	0.738	1.256
	-KEROSENE	6.552	7.528	9.811	11.306
	-WOOD	3.600	3.903	4.103	4.188
3	RURAL AND OTHERS	11.739	11.827	9.768	7.179
	-LPG	0.000	0.000	0.000	0.000
	-KEROSENE	1.174	1.360	1.270	1.041
	-WOOD	10.565	10.467	8.498	6.138

SERVICE SECTOR: TOTAL ENERGY DEMAND

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL DEMAND (TEP)	12546.000	14855.000	17846.000	21325.000
1.1	LPG	239.930	312.760	404.540	583.530
1.2	KEROSENE	612.650	736.750	877.800	949.670
1.3	GASOLINE	3012.400	3157.300	3311.900	3429.900
1.4	DIESEL FUEL	2890.600	3341.400	3818.100	4189.200
1.5	ELECTRICITY	5790.000	6857.100	8207.400	9754.100
1.6	SOLAR AND WIND ENERGY	0.000	449.410	1226.200	2418.100
2	DEMAND STRUCTURE (FRACTION)				
2.1	LPG	0.019	0.021	0.023	0.027
2.2	KEROSENE	0.049	0.050	0.049	0.045
2.3	GASOLINE	0.240	0.213	0.186	0.161
2.4	DIESEL FUEL	0.230	0.225	0.214	0.196
2.5	ELECTRICITY	0.462	0.462	0.460	0.457
2.6	SOLAR AND WIND ENERGY	0.000	0.030	0.069	0.113
3	DEMAND BY SECTOR (TEP)				
3.1	ADMINISTRATION AND PUBLIC SERVICES	4543.800	5846.800	7289.900	8794.200
3.2	COMMERCE, BANKS, AND INSURANCES	659.960	845.190	1112.100	1404.400
3.3	HOTELS, BARS AND RESTAURANTS	1284.100	1780.800	2574.400	3574.200
3.4	PUBLIC LIGHTING	150.140	237.230	386.750	628.890
3.5	WATER PUMPING	408.640	604.670	942.740	1382.800
	-ELECTRICITY	366.880	542.040	855.020	1268.500
	-DIESEL FUEL	41.765	62.628	87.719	114.270
	-SOLAR AND WIND ENERGY	0.000	0.000	0.000	0.000
3.6	FRENCH ARMY	5499.000	5540.000	5540.000	5540.000
	-LPG	132.000	140.000	140.000	140.000
	-KEROSENE	0.000	0.000	0.000	0.000
	-GASOLINE	2370.000	2370.000	2370.000	2370.000
	-DIESEL FUEL	973.000	980.000	980.000	980.000
	-ELECTRICITY	2024.000	2050.000	2050.000	2050.000

SERVICE SECTOR: ELECTRICITY DEMAND

REFERENCE YEAR	1985	1990	1995	2000
TOTAL DEMAND (MWh)	67326.000	79734.000	95435.000	113420.000
1.1 ADMINISTRATION, AND PUBLIC SERVICES	22955.000	27594.000	31635.000	38750.000
1.2 COMMERCE, BANKS AND INSURANCE	7674.000	9827.800	12932.000	16330.000
1.3 HOTELS, BARS, AND RESTAURANTS	7150.300	9413.000	12591.000	16487.000
1.4 PUBLIC LIGHTING	1745.800	2758.500	4497.100	7312.600
1.5 WATER PUMPING	4266.000	6302.800	9942.100	14751.000
1.6 FRENCH ARMY	23535.000	23857.000	23837.000	23837.000

TRANSPORTATION SECTOR: NATIONAL MARKET

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL DEMAND (TEP)	28425.000	35561.000	45819.000	61521.000
1.1	GASOLINE	7634.700	8600.300	9558.200	12385.000
1.2	DIESEL FUEL	16239.000	21152.000	28448.000	39675.000
1.3	JET FUEL	4551.300	5806.800	7413.600	9461.900
2	DEMAND STRUCTURE (FRACTION)				
2.1	GASOLINE	0.269	0.242	0.217	0.201
2.2	DIESEL FUEL	0.571	0.595	0.621	0.645
2.3	JET FUEL	0.160	0.163	0.162	0.154
3	DEMAND BY MODE (TEP)	28425.000	35561.000	45819.000	61521.000
3.1	AIR	4551.300	5808.800	7413.600	9461.800
3.2	BUS	4676.100	6343.400	9057.600	12884.000
3.3	INDIVIDUAL	15590.000	18687.000	23074.000	30712.000
3.4	RAILWAY	1306.000	1666.800	2127.300	2715.100
3.5	MARITIME	710.530	906.840	1157.400	1477.100
3.6	TRUCK	1591.500	2148.500	2989.800	4271.800
4	DEMAND STRUCTURE BY MODE OF TRANSPC‾T (FRACTION)				
4.1	AIR	0.160	0.163	0.162	0.154
4.2	BUS	0.165	0.178	0.198	0.209
4.3	INDUVIDUAL	0.548	0.525	0.504	0.499
4.4	RAILWAY	0.046	0.047	0.046	0.044
4.5	MARITIME	0.025	0.026	0.025	0.024
4.6	TRUCK	0.056	0.060	0.065	0.069

TRA‿SPORT SECT‿R: TOTAL ENERGY DEMAND

	REFERENCE YEAR	1985	1990	1995	2000
1	TOTAL DEMAND (TEP)	154790.000	170360.000	190240.000	215600.000
1.2	AIRPORT	57608.000	57608.000	57608.000	57608.000
1.3	PORT (BUNKERING)	97182.000	112750.000	132630.000	158000.000

TRANSPORTATION SECTOR VARIABLES

	REFERENCE YEAR	1985	1990	1995	2000
1	PASSENGER TRAFFIC (MILLION PASSENGERS X KM)	1809.900	2417.600	3405.200	5027.500
1.1	AIR	32.500	41.479	52.939	67.565
1.2	PUBLIC TRANSPORT	1305.800	1818.700	2671.900	4064.900
	-RAILWAY	277.000	353.530	451.200	575.860
	-ROAD	1027.400	1463.400	2218.500	3486.200
	-MARITIME	1.350	1.723	2.199	2.806
1.3	AUTOMOBILES	470.680	557.490	680.300	895.020
2	PUBLIC TRANSPORT				
2.1	FLEET OF VEHICLES	521.000	673.000	895.000	1208.000
2.2	TRAFFIC (MILLION PASSENGERS X KM)	171240.000	232290.000	321530.000	446950.000
3	AUTOMOBILES				
3.1	FLEET OF VEHICLES (THOUS.)	11.622	12.514	13.998	16.370
4	TRANSPORTATION OF GOODS (MILLION TONNES X KM)				
4.1	TRAFFIC (TOTAL)	139.680	178.760	229.170	294.360
	-ROAD	6.579	8.881	12.359	17.659
	-RAIL	133.100	169.870	216.810	276.710
4.2	FLEET OF VEHICLES	430.000	522.000	721.000	961.000

AGRICULTURAL AND FISHING SECTOR

REFERENCE YEAR	1985	1990	1995	2000
1 DEMAND BY ENERGY TYPE (TEP)	203.270	279.690	342.750	430.000
1.1 DIESEL FUEL AND GASOLINE	116.620	156.290	186.020	225.930
1.2 ELECTRICITY	86.646	123.410	156.740	204.070
1.3 SOLAR AND WIND	0.000	0.000	0.000	0.000
2 DEMAND STRUCTURE (FRACTION)				
2.1 DIESEL FUEL AND GASOLINE	0.574	0.559	0.543	0.525
2.2 ELECTRICITY	0.426	0.441	0.457	0.475
2.3 SOLAR AND WIND	0.000	0.000	0.000	0.000
3 DEMAND BY ENERGY USE (TEP)				
3.1 TRACTORS	0.000	0.000	0.000	0.000
-DIESEL FUEL	0.000	0.000	0.000	0.000
3.2 IRRIGATION	0.000	0.000	0.000	0.000
-DIESEL FUEL	0.000	0.000	0.000	0.000
-ELECTRICITY	0.000	0.000	0.000	0.000
-SOLAR AND WIND	0.000	0.000	0.000	0.000
3.3 FISHING	116.620	156.290	186.020	225.930
-DIESEL FUEL	116.620	156.290	186.020	225.930
3.4 FOOD PRESERVATION	86.646	123.410	156.740	204.070
-DIESEL FUEL	0.000	0.000	0.000	0.000
-ELECTRICITY	86.646	123.410	156.740	204.070
-SOLAR AND WIND	0.000	0.000	0.000	0.000
4 DEMAND STRUCTURE BY END-USE (FRACTION)				
4.1 TRACTORS	0.000	0.000	0.000	0.000
4.2 IRRIGATION	0.000	0.000	0.000	0.000
4.3 FISHING	0.574	0.559	0.543	0.525
4.4 FOOD PRESERVATION	0.426	0.441	0.457	0.475

CHAPTER 9

ENERGY CONSERVATION AND DEMAND MANAGEMENT

The various scenarios studied in the preceding chapters assume a normal evolution of the supply and demand of energy, in response to a growing GDP which is more or less rapid according to the scenario.

However, as shown in Chapter 5, there exists a variety of techniques and initiatives which, over the short and mid term, are capable of significantly modifying the demand for energy either in absolute terms, or in terms of the form of energy supplied.

These measures concern the whole energy supply and demand system--production, distribution, and consumption. The introduction of these measures depends on either technical progress, demonstrated economic benefits, or on government decree.

This chapter presents a technical and economic review of several of these measures and techniques which could be rapidly introduced, and discusses their application and impact.

The first section deals with final energy consumption and the efficiency of energy use; the second section looks at the system of energy production and supply.

9.1. MANAGEMENT OF FINAL ENERGY DEMAND

It should be stated at the outset that in no case will the introduction of energy conservation measures have an adverse impact on the consumer.

The actions envisioned will neither reduce the quality of life, nor increase the cost of energy.

On the contrary, the measures discussed here should improve the quality of life, and reduce the cost of energy for the individual consumer.

9.1.1. Residential Sector

9.1.1.1. Energy Conservation in Refrigeration

The analysis of electricity consumption in the residential sector reviewed in some detail in Chapter 1, clearly shows the significant contribution of refrigeration to the monthly electricity bill, particularly in the low-income households.

The high electricity consumption of the domestic refrigerator in Djibouti is a result of:

- the use of refrigerators which are not adequately thermally insulated, given the high ambient temperatures of Djibouti.

- the common practice of placing refrigerators in outside courtyards, often in the sun.

- the lack of maintenance and servicing.

To improve this situation, which leads to an excessive consumption of electricity, and which significantly reduces the lifetime of the refrigerators, there are two complementary measures which can be taken.

- For new refrigerators, legislation could require that imported units have an adequate level of thermal insulation. This measure should be accompanied by a strict controls to ensure that the price of refrigerators is not raised unfairly.

- For the refrigerators already in service, a program to insulate the majority of the units could be implemented.

After having devised and tested a simple method of attaching additional insulation to a refrigerator, ISERST recently organised 2 test programs of the technique. One program insulated about 100 refrigerators in low-income households, the other insulated about the same number of refrigerators in the Peltier hospital and in several dispensaries in Djibouti ville. Each of the programs was successful, both in terms of user acceptability and the amount of energy saved.

There are different ways to disseminate this technique in the residential sector in order to reduce the consumption of electricity and monthly electricity bills. For instance, the consumers could pay for the work themselves, or the Government could launch a state-run program, using either its own funds or those of another agency.

The idea of spending money in order to be able to save a larger amount in a few months' time may not be readily accepted by the majority of households in Djibouti. This presumption makes the first solution questionable, unless perhaps EdD agrees to permit an appropriate surcharge to be placed on the bimonthly electricity bills.

The second approach seems therefore the more attractive, particularly since circumstances are such that a program of this kind could be started in the near future. In fact, the Government has agreed to use the excess profits earned by EdD (due to the fall in the price of petroleum at the end of 1985), to fund a project led by ISERST and the Energy Service which will insulate 11,000 refrigerators and replace 15,000 incandescent lamps with fluorescent lights.

This ambitious project is discussed in greater detail in reference /9.1/, which presents the background to this proposal and sets out the actions which will be undertaken.

The report cited above shows that paying 4,000 FD for the insulation of a typical refrigerator generates savings of about 8,700 FD per year--a payback time of 5 months. The major benefits of the project are:

- a reduction in monthly electricity bills,
- lower temperatures inside the refrigerator,
- a longer lifetime for the refrigerator,
- a reduction in foreign exchange costs,
- the creation of employment,
- the strengthening of the thermal insulation industry.

The impact of this program on the overall consumption of electricity by the residential sector is by no means negligible.

Assuming an annual saving of 350 kWh of electricity per refrigerator, and 11,000 units insulated, total energy savings amount to 3,850 MWh -- 20 % of the energy demand for refrigeration, and 6 % of the total demand for electricity in the residential sector.

Finally, with regard to the economics of such a project, annex 9.1 presents economic and financial analyses which clearly show the benefits of this initiative. The benefit/cost ratio for households, for instance, is greater than 12.

9.1.1.2. Energy Conservation in Lighting

Although lighting accounts for less electricity consumption than refrigeration, there exists measures which could produce appreciable savings of energy over the short term.

Among these measures, the substitution of fluorescent tubes for incandescent bulbs is the most important.

In contrast to the situation in many western households, fluorescent lighting in Djibouti is well accepted, and would be even more widespread were it not for the cost of the fixture. The fluorescent unit costs about 2,000 FD for the regulator, starter, ballast, and tube; whereas an incandescent light bulb costs only 150 FD.

However, it is proposed that the project cited earlier, which will insulate 11,000 refrigerators in Djibouti, should also replace an incandescent lamp with a fluorescent light in 15,000 households /9.1/.

The fluorescent tubes to be installed will conform with the appropriate electrical standards, and will have a power factor of at least 0.85; there will be no adverse effect on the electrical supply system.

Assuming an energy saving of 86 kWh/year for each light, 15,000 installations will generate electricity savings of 1,300 MWh per year--30 % of the total electricity demand for lighting, and 2 % of the total electrical demand of the residential sector.

Other actions concerning lighting have already been carried out in the service sector, including efforts to make employees more aware of the advantages of natural lighting, and of the energy wasted by lights left on unnecessarily. In addition, all the lights in the corridors of the principal Government building (the Cité Ministérielle) have been replaced by compact fluorescent lamps. This substitution should produce savings of 1.2 million FD per year.

The tables in annex 9.2 show the economic and financial benefits of the proposed measures, which will accrue to both the individual and to the State.

9.1.1.3. Energy Conservation in Air Conditioning

There is an important potential for energy savings in air conditioning, both in the residential sector and in the service sector.

Some of the measures which should be pursued as a matter of priority include: making the public more aware of the high cost of air conditioning; the importation of air conditioning units adapted to the local climate; the observance of simple maintenance procedures, and the more widespread use of thermal insulation in building construction. Together, these measures would significantly reduce the consumption of electricity for air conditioning necessary to maintain a given level of comfort.

Of these measures, the introduction of technical standards for the use of thermal insulation in buildings is the most important.

At the present time, there are no regulations which require thermal insulation to be installed in new buildings. Despite summer temperatures approaching 50 °C, and exceptionally strong sunshine, anyone can build a house with absolutely no thermal insulation. It is obvious that operating an air conditioner in such a building in the summer requires far more energy, and costs far more money in electricity bills, than would be required in a building which was better insulated.

For several years now, countries with colder climates have imposed regulations requiring the use of thermal insulation in buildings (coefficients C, B, or G in France, for example), which have substantially reduced energy bills for both the individual consumer and the State.

In the tropical countries, the technical approach to efficient energy use should be the same. It is in both the individual and the public interest to do everything possible to prevent the needless waste of energy.

In Djibouti, after the construction of a number of prototype energy efficient buildings, the market for thermal insulation has picked up somewhat; a new technique for the application of insulation has even been introduced.

The Division of Urban Planning and Housing in the Ministry of Public Works, together with ISERST, has drafted building codes for the use of thermal insulation in new buildings situated in particular areas of Djibouti ville. These regulations concern:

- roof insulation, equivalent to 8 cm of polystyrene,
- floor slab insulation, equivalent to 4 cm of polystyrene,
- the use of double glazing.

The insulation of the exterior walls is deliberately excluded from these first regulations. To add the thermal insulation of walls to the requirements listed above would significantly increase the cost of construction, and might jeopardize the acceptance of the regulations.

It should be noted that the owner of a house or a building seldom lives in it; more often, the building is an investment which, like most investments, is intended to earn as much as possible. The investor does not pay the energy bills. This may perhaps explain why the use of thermal insulation is not more widespread.

However, it is in this sector that energy conservation is most important, since the widespread use of thermal insulation would significantly reduce the peak demand for electricity supplied by EdD, and thus would also reduce the necessary installed capacity.

In 1985, residential air conditioning consumed more than 30,000 kWh of electricity--48 % of the electricity used in this sector. In the service sector, air conditioning accounts for an even greater part of the sectoral electrical demand, consuming approximately 40,000 kWh, about 60 % of the total demand.

Installing thermal insulation in buildings could reduce the consumption of electricity by 30 %, or more than 20,000 MWh per year for the residential and service sectors combined. This potential saving is about 15 % of the total electricity demand for the country.

Apart from non-resident building owners, for whom the benefits are minimal, the advantages of thermal insulation of buildings are gained by:

- EdD, since the peak electrical demand will be reduced, and the need for excess capacity will diminish,

- The State, since foreign exchange costs will decline, and electricity bills for Government offices will be reduced,

- House residents, who will pay lower electricity bills for air conditioning,

- Private companies and firms, who will also pay less for air conditioning,

- Firms manufacturing and installing thermal insulation, who will find a larger market for their services.

It is therefore important to encourage the thermal insulation of both new and existing buildings, not only by demonstration and by example, but also by the promulgation of the building codes now under review.

9.1.1.4 Energy Conservation in Cooking

Cooking accounts for 72 % of household energy consumption. The energy demand measured in TPE is 7.5 times larger than the demand for air conditioning.

The energy consumed for cooking varies according to the socio-economic level of the household and the geographic area. In Djibouti-ville, the use of kerosene is widespread-- 85 % of households in the town use this fuel for cooking.

In the secondary towns, kerosene is still the most common fuel for cooking, but it is seldom used in the more isolated regions where only about 10 % of households use this fuel.

The study conducted by Briane in August 1986 on the efficiency of the kerosene stoves used in Djibouti, measured thermal efficiencies between 50 % and 64 %. These results are presented in more detail in reference /9.2/.

Briane's analyses led him to the following conclusion:

> "In Djibouti, the kerosene stoves show very satisfactory performance, even when the wicks are badly regulated.
>
> The tests carried out also showed that a media campaign designed to improve the way the stoves are used would serve no useful purpose.
>
> However, it would be useful to make the user more aware of the importance of covering the cooking pot, as well as the need to periodically clean the burner."

It is the latter measures, encouraged by means of an appropriate media campaign, which could lead to a reduction in the consumption of kerosene.

With regard to the consumption of wood, the problem is quite different. The use of the 3-stone fire for cooking leads to an excessive consumption of fuelwood which often contributes to the degradation of the forest resources.

Although a quantitative survey of fuelwood resources has not yet taken place, it is nonetheless essential that every effort be made to improve the efficiency with which wood is used for cooking.

At the beginning of 1987, ISERST constructed several improved cookstoves made out of fired bricks and clay. These stoves were installed in 4 schools in the north of the country which together provide meals for over 100 pupils each day. The efficiency of the improved stoves is about 30 %, twice that of the rudimentary stoves previously used.

This initiative, which was designed to test the technique and to confirm its acceptability, should be extended to include not only the centres of communal cooking, but also the households which cook with wood.

The dissemination of this technology will require the training of village-level trainers who, in turn, will encourage the use of the new stoves in their village.

Biomass energy use accounts for just over 11,000 TPE or 15 % of total final energy demand. This contribution, however, is often to the disadvantage of local biomass resources, and is a factor in the continuing desertification of several regions of the country.

The implementation of a project designed to disseminate improved stoves is therefore a priority, not only from an energy perspective, but also from the point of view of environmental protection.

9.1.2. Agriculture and Livestock Raising

9.1.2.1. Substitution of Petroleum Fuels for Water Pumping in the Rural Areas

Water is a vital resource in Djibouti, particularly in those areas still seriously affected by the drought.

There are several ways to pump water from a shallow well, or a tube well, to the surface for consumption by people or animals, or for irrigation. In particular, the development of photovoltaic pumps and modern windpumps offers an opportunity to reduce the consumption of gasoline or Diesel fuel by motor pumps.

In order to compare these technologies in a more rigorous manner, a detailed economic analysis of the different techniques has been performed.

Figure 9.1.1 presents the results of a part of this study. The cost of pumping water using four different technologies is shown graphically as a function of the hydraulic energy demand.

The hydraulic energy required to pump water depends on the depth of the water and the height to which it is pumped (represented by the total dynamic head), and the rate of flow of the water. This relationship can be expressed as follows:

$$E = 2.275\ Q\ H \qquad \text{Watt-hours (Wh)}$$

where Q is the flow of water in m3/day, and H is the total dynamic head in metres.

Figure 9.1.1. shows that photovoltaic pumps are the most economic alternative for hydraulic energy demands of less than about 300 Wh/day. For loads greater than this, motor pumps appear to be more economic than all the other alternatives.

However, it is necessary to distinguish between shallow wells, i.e. wells where the water level is less than 6 m, and tube wells, defined here as any well where the water level is at a depth greater than 6 m.

Surface mounted motor pumps cannot draw water from depths of much more than 6 m at sea level. Below this depth, an electric submersible pump, or another applicable pumping technology, must be used.

Figure 9.1.2. shows the results of an analysis of the cost of pumping for the case of the tube wells. Again, photovoltaic pumps are the more economic option for the low hydraulic energy demands: those less than about 400 Wh/day. Above this hydraulic load, windpumps become more economic.

For sites where mean windspeeds are low--less than 3 m/s--photovoltaic pumps are the most economic option up to a hydraulic load of about 1,100 Wh/day. Above this level, submersible electric pumps driven by Diesel generators are the most economic option.

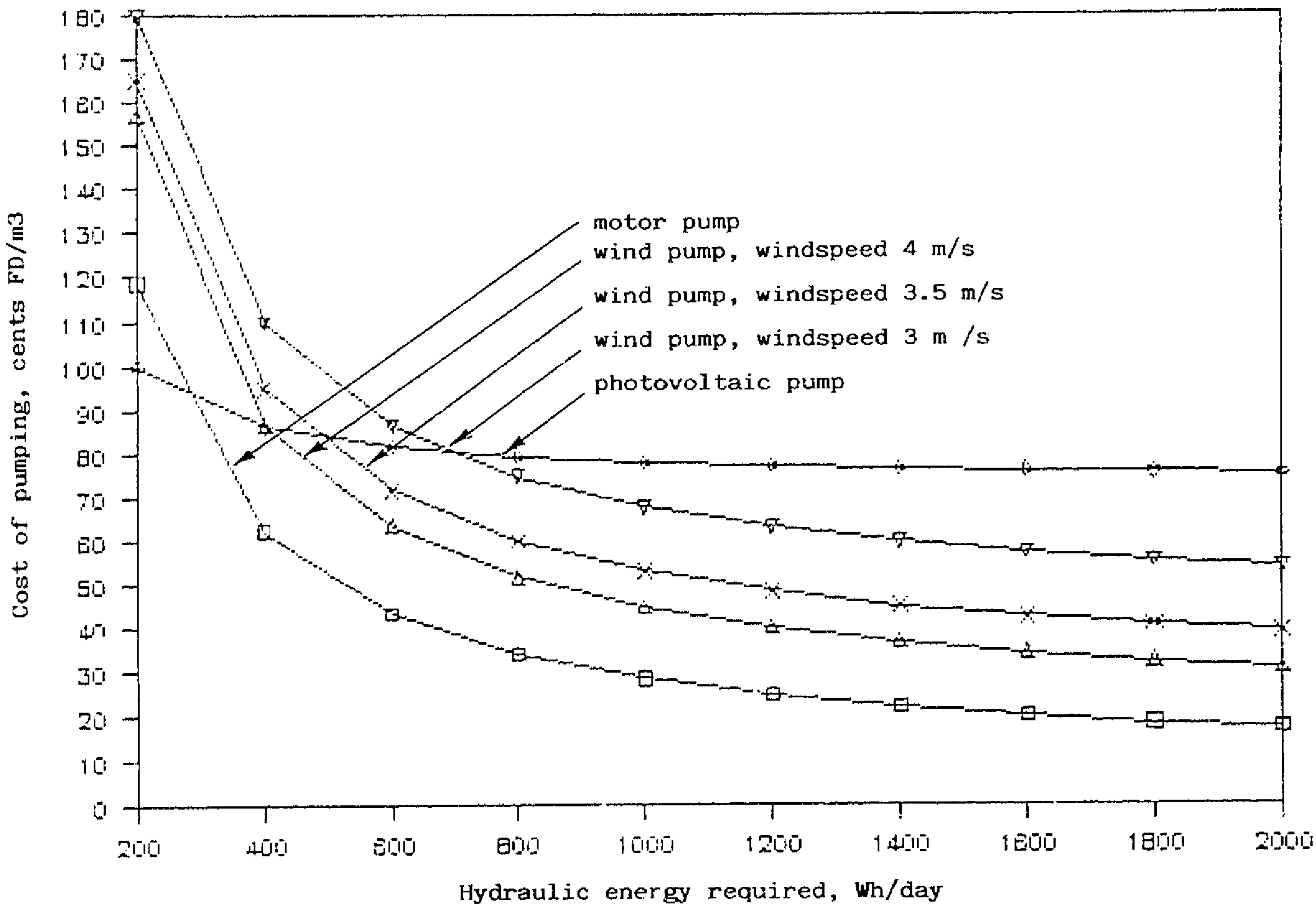


Figure 9.1.1 Cost of Pumping Water from Shallow Wells

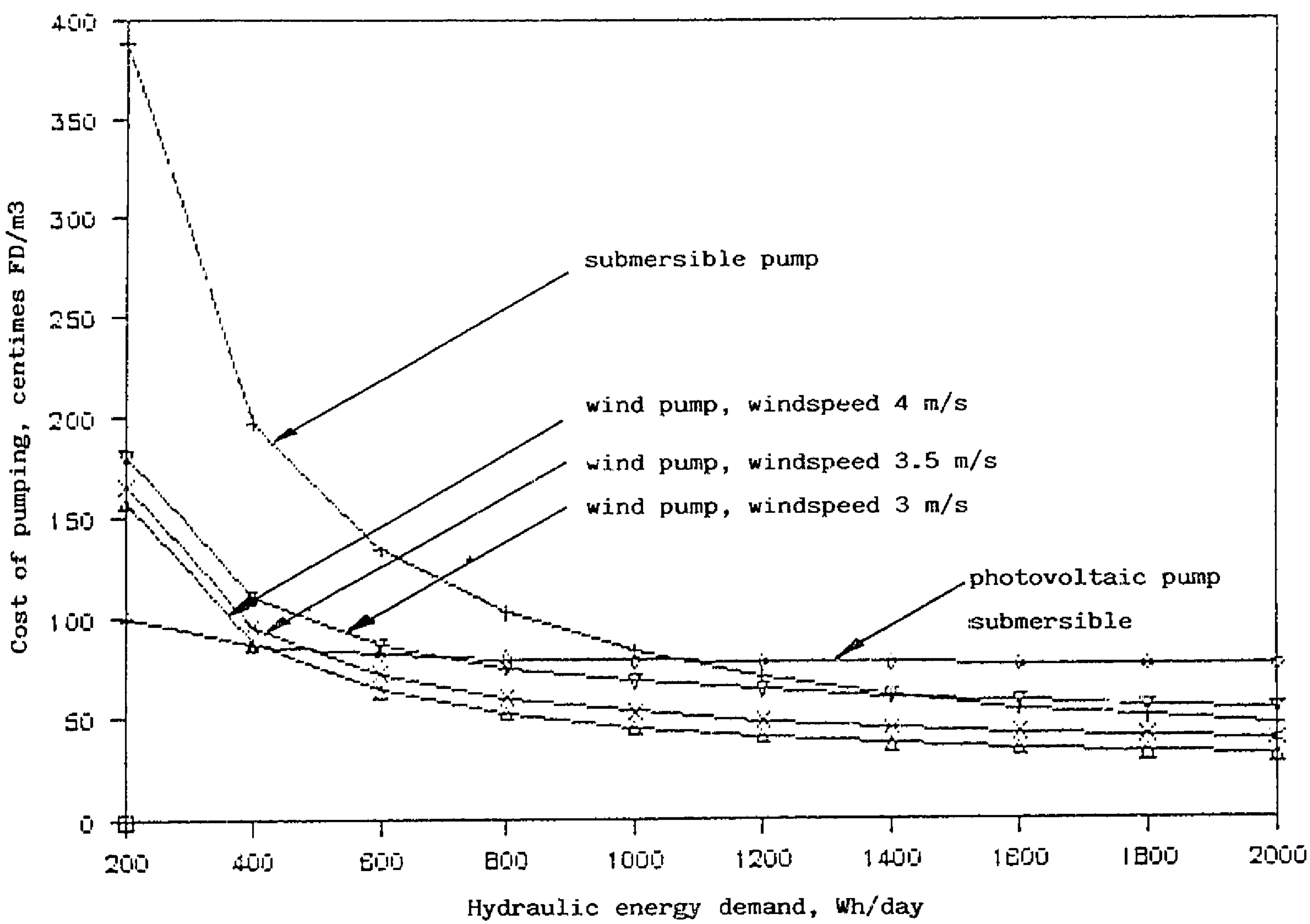


Figure 9.1.2. Cost of Pumping Water from Tube Wells

Table 9.1.1. sets out these results in a different manner. For a range of typical situations defined by the total dynamic head (TDH) and the flow of water from the well, the most economic pumping option is indicated.

Table 9.1.1. Economic Options for Water Pumping

SITE	TDH(1) metres	FLOW m3/day	ECONOMIC OPTION	REMARKS
Shallow well	5	20	PV pump	Floating or surface mounted
Shallow well	6	30	Motor pump	
Shallow well	20	40	Motor pump	Shallow well, water pumped to a higher level
Tube well, shallow	10	10	PV pump	Submersible
Tube well, average depth	20	15	Wind pump (V > 2.5 m/s)	If windspeeds are less than 2.5 m/s, a PV pump should be selected.
Tube well, deep	50	15	Wind pump (V> 3 m/s)	If windspeeds are less than 3 m/s, an electric submersible pump and generator should be chosen.
Tube well, deep	80	15	Wind pump (V > 3.5 m/s)	If windspeeds are less than 3.5 m/s an electric submersible pump and generator should be chosen.

(1) Total Dynamic Head (TDH) includes the suction head, the discharge head, and all hydraulic energy losses.

Given the interest in hand pumps, this pumping option was also studied. Figure 9.1.3 presents graphically the results of the analysis. Two curves are shown for hand pumps. The upper curve is the cost of pumping water when the opportunity cost of labour is included in the calculation. This case might be appropriate for a situation where the water is used for irrigation.

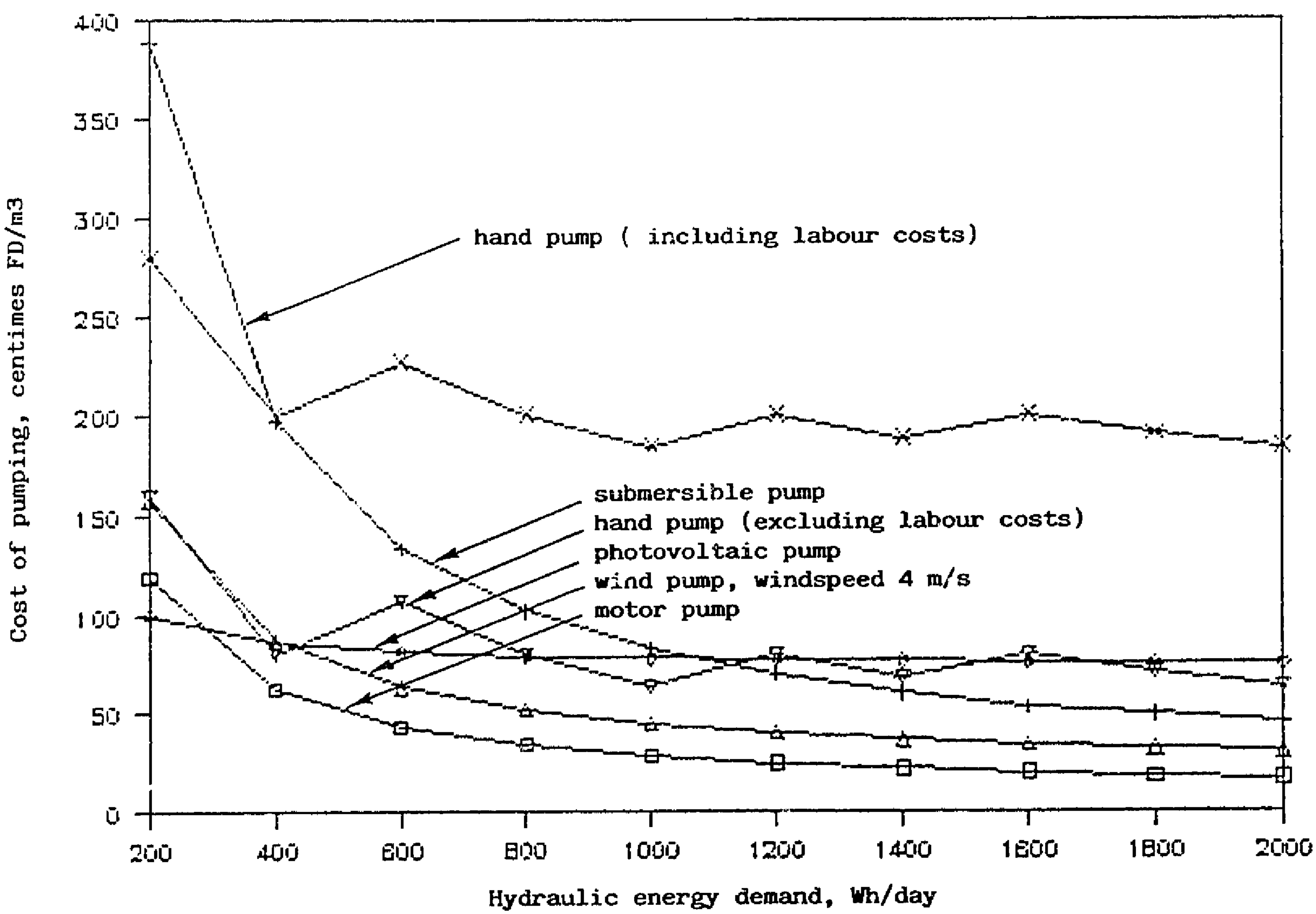


Figure 9.1.3. Cost of Pumping with Hand Pumps

The lower curve is the cost of pumping water when the opportunity cost of labour is neglected. This case being more appropriate for a situation where the pump provides drinking water in a village.

The curves do not decline in a smooth manner since increasing hydraulic loads require the installation of additional pumps. Thus, assuming a hand pump gives on the average 500 Wh/day of hydraulic energy, 2 hand pumps would be required to satisfy a load of 600 Wh/day.

The economics of hand pumps are clearly very sensitive to the assumptions made concerning the opportunity cost of labour. If this cost is included, hand pumps do not appear to be able to compete with the alternative pumping technologies.

On the other hand, if the cost of labour is assumed to be zero, hand pumps are a competitive option. Hand pumps, of course, may offer other advantages which do not appear in a strictly economic analysis.

9.1.3 Industry

Although the consumption of energy by the industrial sector is only 5 % of total energy demand, improvements in energy efficiency should not be neglected. The measures to be undertaken depend on the industry under consideration.

One measure, perhaps applicable to the sector as a whole, might be to shift the hours of production to those hours when the demand for electricity is at a minimum. However, disaggregation of the demand for electricity shows that the demand of the industrial sector makes very little contribution to the peak demand.

The measures recommended here concern industrial process heat, the consumption of electricity, and the organization of the processes of production.

The generation of heat, which mainly concerns the dairy (Laiterie de Djibouti), could include the use of solar collectors for water preheating. Very few solar water heaters are in use in Djibouti, because the temperature of the water supply at the tap is already relatively high. However, there are a number of instances where solar water heaters might prove economic, given the high levels of insolation found in the region.

An interesting example of direct combustion using appropriate technology can be found at a small brick-making factory on the outskirts of Djibouti-ville. This factory manufactures fired bricks and claustras made from local clays. The furnace is fuelled with a mixture of waste oils and water which generates very high temperatures.

This technique, which not only saves energy but which also protects the shallow aquifers from the waste oils which would otherwise be dumped outside of the town, could be extended to other small industries such as the lime kilns proposed for the region of Dorale.

Optimizing the consumption of electricity depends on achieving an acceptable power factor. For certain industries, notably the container terminal at the port, it appears that the power factor of the electrical equipment could be significantly improved. The techniques available for improving the power factor of the terminal should therefore be studied.

Better management of the production system can also lead to the conservation of energy; the dairy is an example which comes to mind. Each day the dairy produces a certain volume of milk and a certain number of small tubs of yoghurt. This production involves heating the sterilization and pasteurization vats.

During 1986, the managers of the dairy tested a new schedule where what was formerly 2-day's production was produced in a single day. The new schedule resulted in an energy saving of close to 40 %.

This example shows that a critical analysis of the production processes in the various industries could lead to appreciable energy savings.

9.1.4. Transportation

Energy conservation in the transport sector involves a number of initiatives which affect both public transport and the use of private vehicles.

9.1.4.1. Buses and Minibuses

Since 1982, the number of buses and minibuses has grown from 200 vehicles to the present figure of more than 500 vehicles. The number of passengers has not increased at the same rate. There is therefore an excess of vehicles in service, given the demand for public transport.

Long lines of buses and minibuses cause traffic jams in the narrow streets of Djibouti ville, one result of which is an excessive consumption of fuel.

The introduction of the A and B system, described in annex 9.5, would reduce the frequent vehicle stops, lessen the rapid mechanical deterioration of the vehicles, extend the lifetime of the tyres, and above all produce significant energy savings.

The resulting reduction in the consumption of fuel is estimated at more than 30 %. For example, a 25-seater bus should consume about 15 litres of fuel per 100 km; typical consumption for a bus in Djibouti is almost twice this figure.

Other simple measures such as better maintenance, better driving skills, less frequent use of air conditioning, etc., would also produce significant energy savings. These measures were included in the energy conservation media campaign conducted in 1986.

9.1.4.2. <u>Bus Terminal and Garage</u>

At the moment, there is no central garage or maintenance centre where the owners of the buses and minibuses may take their vehicles for routine maintenance and servicing. This lack of facilities contributes to the poor regulation of the engines, and to the generally bad condition of the vehicles.

To improve the situation, it is recommended that a bus terminal and maintenance centre be constructed. These facilities would allow the maintenance and the servicing of the buses and minibuses to carried out on a regular basis.

9.2. MANAGEMENT OF THE PRODUCTION AND SUPPLY OF SECONDARY ENERGY

The secondary energy forms which are part of the energy demand and supply picture in Djibouti are petroleum fuels, electricity, and charcoal.

9.2.1. Petroleum Fuels

Djibouti imports relatively large amounts of refined petroleum products in the form of fuels, and this situation is not expected to change in the foreseeable future. Although obviously unable to influence world oil prices, Djibouti can still promote measures designed to change both the level and the mix of fuel consumption.

For example, the substitution of the light fuel oil, used by the 15 MW generators of EdD, by a heavier grade of fuel oil will significantly reduce EdD's fuel costs. However, this substitution requires certain modifications to be made to the existing equipment, and results in increased maintenance and a shorter lifetime for the generators.

This example of fuel substitution should be studied in more detail to determine if the benefits outweigh the costs.

The use of more effective lubricants might also prove to be economic; this possibility should also be studied.

More generally, a study of the system of petroleum fuel supply, transportation, and distribution, would appear to be essential if a coherent pricing policy for the petroleum fuels consumed in Djibouti is to be formulated.

9.2.2. Charcoal

The method of making charcoal most commonly found in Djibouti is the open fire. It is the simplest procedure, but from an energy point of view it is the least efficient.

The energy efficiency of this rudimentary technique, defined as the ratio of the energy value of the charcoal produced to the energy value of the wood used, is about 20 % to 25 %. Relatively simple but improved techniques can produce efficiencies of about 50 %.

The open fire technique is no longer widely used in Africa. More common is the technique where a stack of wood is covered with vegetal matting or earth, or where this is carried out in a pit. These techniques require a certain expertise and care if the efficiency is to be acceptable.

The use of the open fire technique often indicates that the manufacture of charcoal is a secondary economic activity carried out by persons who are not professional charcoal-makers. This is certainly the case in Djibouti, where the production of charcoal brings an occasional and supplementary income.

The open fire technique has the advantage that it does not require wood which is of roughly uniform length and diameter. Tree stumps, trunks, and branches are all piled up together.

This is not possible when the wood is stacked; the stack must be closed so that the vegetal or earth cover does not fall into the stack, and thus allow the wood to burst into flame.

There are several simple methods of making charcoal which are relatively efficient. The technique proposed here is the covered pit: a small hand-dug pit, covered with sheets of corrugated iron, with short narrow chimneys to control the entry of air, is a technique which appears to be applicable to Djibouti.

This technique, which is described in more detail in annex 9.6, has several advantages:

- the investment required is very small.
- the method is not too different from the rudimentary technique which is in widespread use.
- it produces small quantities of charcoal, several steres at a time, which is appropriate for Djibouti.
- it does not require a vegetal cover.

After testing the technique itself, ISERST carried out a series of demonstrations at Obock and Tadjourah in order to introduce the new technique to local charcoal-makers. These demonstrations were well received, since the amount of charcoal produced from a volume of wood was clearly much greater than that obtained using the open fire technique. The energy efficiency of the covered pit method is more than 50 %.

9.2.3. Electricity

Energy conservation and demand management measures are applicable to the total system of electricity production, transmission, distribution, and consumption. These measures concern, inter alia:

- the installation of more efficient power generation systems, and a reduction in auxiliary consumption.

- the reduction of energy losses in transformers, and in transmission and distribution.

- the management of electricity demand with the aim of reducing peak demand.

The management of electrical demand can be facilitated by means of a tariff structure which aims to reduce the peaks in the demand curve. A reduction in the peak electrical demand, in principle, permits a reduction in total installed generating capacity. This means a lower investment in equipment, a better utilization of existing equipment, less fuel consumed per kWh generated, and thus a lower cost of production.

To reduce the consumption by auxiliary equipment, it would be useful to study the possibility of replacing the existing cooling system, where the generators are air-cooled, with a water-cooled system using sea water. While air temperatures often reach 45 °C or even 50 °C in the summer, sea water temperatures remain fairly constant at around 30 °C. This temperature difference could have a significant positive impact on engine performance.

The large amount of waste heat produced by the generators at Boulaos results in only an average efficiency of production. There are several ways to exploit this thermal energy. The heat could be used to power a gas turbine generator, or the heat could be used to desalinize sea water. These options should be studied in more detail.

EdD has also designed a training program for its personnel which should improve the operation of the agency, both administratively and technically, and which should eventually lead to more efficient electricity production, transmission, and distribution. A project has been proposed to this effect.

With respect to the summer daily demand curve, there are 2 clear peaks. The first occurs at about 1 p.m., the other at around 1 a.m. The introduction of an appropriate tariff structure, or of other incentives, could produce a better distribution of the demand, and therefore of production. An initial study based on the marginal cost of electricity generation has proposed an appropriate set of tariffs. However, this tariff structure needs to be refined to take account of the Government's social and economic policies and other considerations.

The final decision concerning the future mode of electricity production--Diesel generators, geothermal power, or other--will depend on technical and economic data which will not be available until the studies and research programs now underway are completed. However, enough information exists to permit pre-feasibility analyses of several of the options to be conducted, as discussed in Chapter 8. These analyses will be refined in due course.

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ANNEX 9.1 Energy Conservation in Refrigeration

TABLE A 9.1.1 ECONOMIC AND FINANCIAL ANALYSIS

	DJIBOUTI FRANCS (1986)									RATIO BENEFIT/COST	
	YEAR							NET PRESENT VALUE			
	1	2	3	4	5	6	7	AT 5%	AT 10%	AT 5%	AT 10%
1. AT MARKET PRICE (FINANCIAL ANALYSIS)											
1.1 INVESTMENTS	4000	0	0	0	0	0	0	4000	4000		
1.2 ENERGY SAVINGS PER HOUSEHOLD (*)	8700	8700	8700	8700	8700	8700	8700	52858	46591		
1.3 FINANCIAL CASH FLOW	4700	8700	8700	8700	8700	8700	8700	48858	42591	13.21	11.65
2. AT PRICE EX. TAX (ECONOMIC ANALYSIS)											
2.1 INVESTMENTS	3566	0	0	0	0	0	0	3566	3566		
2.2 ENERGY SAVINGS BY THE COUNTRY (*)	1386	1386	1386	1386	1386	1386	1386	8421	7422		
2.3 ECONOMIC CASH FLOW	-2180	1386	1386	1386	1386	1386	1386	4855	3856	2.31	2.01
2.4 FOREIGN EXCHANGE CASH FLOW (**)	-1458	1216	1216	1216	1216	1216	1216	4714	3838		

(*) Assumptions:
- Energy savings per household: 348 kWh/year
- Specific fuel consumption: 231 gr/kWh
- Cost of electricity: 25 FD/kWh
- Price of fuel (fuel oil and Diesel fuel): 17246 FD/tonne

(**) % of foreign exchange
- Investments: 75%
- Fuel: 87.7%

ANNEX 9.2 ENERGY CONSERVATION IN HOUSEHOLD LIGHTING

TABLE A 9.2.1 ENERGY CONSERVATION IN HOUSEHOLD LIGHTING — FINANCIAL ANALYSIS

YEAR	DJIBOUTI FRANCS (1986)						
	COSTS			SAVINGS			CASH FLOW
	INVESTMENT FOR INSTALLATION	FLUORESCENT LIGHTS	TOTAL	LAMP BULBS SAVED	ENERGY SAVED PER HOUSEHOLD (*)	TOTAL	
1	2800	200	3000	329	2160	2489	-511
2	0	0	0	329	2160	2489	2489
3	0	0	0	329	2160	2489	2489
4	0	200	200	329	2160	2489	2289
5	0	0	0	329	2160	2489	2489
6	0	0	0	329	2160	2489	2489
7	0	200	200	329	2160	2489	2289
8	0	0	0	329	2160	2489	2489
9	0	0	0	329	2160	2489	2489
10	0	200	200	329	2160	2489	2289
11	0	0	0	329	2160	2489	2489
12	0	0	0	329	2160	2489	2489
13	0	200	200	329	2160	2489	2289
14	0	0	0	329	2160	2489	2489
15	0	0	0	329	2160	2489	2489
NET PRESENT VALUE							
AT 5 %			3562			27126	23564
AT 10 %			3411			20824	17413
RATIO BENEFIT/COST							
AT 5%							7.61
AT 10%							6.05

(*) Under the following assumptions:
- 6 hours a day of lighting
- Average saving per fluorescent tube: 86kWh/year
- Cost of electricity: 25 FD/kWh

TABLE A 9.2.2 ENERGY CONSERVATION IN HOUSEHOLD LIGHTING ECONOMIC ANALYSIS

YEAR	DJIBOUTI FRANCS (1986)							
	COSTS			SAVINGS			CASH FLOW	
	INVESTMENT FOR INSTALLATION	FLUORESCENT LIGHTS	TOTAL	LAMP BULBS SAVED	ENERGY SAVED PER HOUSEHOLD (*)	TOTAL	ECONOMIC	FOREIGN EXCHANGE (**)
1	2534	172	2706	282	343	625	-2081	-1226
2	0	0	0	282	343	625	625	543
3	0	0	0	282	343	625	625	543
4	0	172	172	282	343	625	453	396
5	0	0	0	282	343	625	625	543
6	0	0	0	282	343	625	625	543
7	0	172	172	282	343	625	453	396
8	0	0	0	282	343	625	625	543
9	0	0	0	282	343	625	625	543
10	0	172	172	282	343	625	453	396
11	0	0	0	282	343	625	625	543
12	0	0	0	282	343	625	625	543
13	0	172	172	282	343	625	453	396
14	0	0	0	282	343	625	625	543
15	0	0	0	282	343	625	625	543
NET PRESENT VALUE								
AT 5 %			3186			6812	3622	3693
AT 10 %			3060			5229	2169	2429
RATIO BENEFIT/COST								
AT 5%								2.14
AT 10%								1.71

(*) Assumptions:
- Energy savings per household: 86 kWh/year
- Specific fuel consumption: 231 gr/kWh
- Price of fuel (fuel oil and Diesel fuel): 17276 FD 1986/tonne

(**) % of foreign exchange:
- Installation: 64%
- Fluorescent tubes: 86%
- Lamp bulbs: 86%
- Fuel: 87.7%

ANNEX 9.3. IMPROVED COOKSTOVES

The traditional way of cooking in the nomad and village households is to cook using 3 large stones and an open fire. The efficiency of this simple stove is very low, about 12 % to 15 %, because so much heat is lost from the open fire.

There are basically 2 types of improved stoves which might be applicable to Djibouti.

- Metal stoves, which are more generally found in the urban areas, and which are made by local artisans.

- Mud stoves, made out of clay, sand, and sometimes straw or animal wastes, which can be constructed by the user and which are often found in the rural areas.

Both types of stoves can be designed around a particular size of cooking pot. This improves the thermal efficiency which can be as high as 30 %.

Given the pattern of fuelwood use in Djibouti, the mud stove design is considered to be more appropriate. This stove has been tried out in 4 schools in the north of the country, and the consumption of fuelwood was reduced by 50 % to 60 %.

The cost of this type of stove is practically nothing, since the materials used in its construction are found almost everywhere, and are freely available.

ANNEX 9.4 ECONOMIC ANALYSIS OF WATER PUMPING TECHNOLOGIES

This study evaluated 5 water pumping technologies: motor pumps, submersible electric pumps with Diesel generators, wind pumps, photovoltaic pumps, and hand pumps. Table A 9.4.1 shows the principal technical and economic characteristics of the various technologies.

The results of this analysis are presented in Tables A 9.4.2 and A 9.4.3. The rate of interest used for the calculation of the capital recovery factor was 10 %.

Table A 9.4.1 Technical and Economic Parameters of the Water Pumping Technologies

Technology	Dimension	Investment FD	Installation FD (2)	Maintenance, FD/yr	Fuel, ml/ m3.m (3)	Life-time, years
Motor pump	E/(hR) (Watts)	50,000/kW (min. 80,000 FD)	-	50,000	4	3
Submersible pump	E/hR	60,000/kW	-	) 200,000		2
generator	(Watts)	90,000/kW	-	)	4	4.75
Wind pump	E/(2.4*V3) m2	80,000/m2	700,000	20,000	-	15
Photovoltaic pump	E/1.3	300/Wp(4)	-	) 20,000	-	3
Panels (1)	E/1.3 (peak watts)	1,700/Wp	-	)	-	15
Hand pump	E/500 (number)	141,600 each	-	35,000	-	2

E = hydraulic energy demand, watt-hours
h = hours of use per day, 4 h for a motor pump, 6 h for a submersible pump
R = system efficiency: 0.3 for a motor pump, 0.2 for a submersible pump with generator
V = mean windspeed at the site, m/s.

1. The cost includes the balance of system components
2. Neglected except for the windmills where this includes transport
3. Consumption in ml/day per (m3/day of water pumped x total dynamic head in metres)
4. Wp = Peak watts

Table A 9.4.2 Cost of Pumping Water from Shallow Wells, centimes FD/Wh

	HYDRAULIC ENERGY DEMAND, Wh/day							
TECHNOLOGY	200	400	600	800	1000	2000	3000	4000
Motor pump (based on petroleum at $ 20/bbl)	118.5	62.2	43.4	34.1	28.4	17.4	13.1	13.9
Windpumps, V = 4.5 m/s	151.8	81.8	58.4	46.8	39.8	25.8	21.1	18.8
4.0	156.8	86.8	63.4	51.8	44.8	30.0	26.1	23.8
3.5	165.0	95.0	71.7	60.0	53.0	39.0	34.4	32.0
3.0	179.8	109.7	86.4	74.7	67.7	53.7	49.1	46.7
2.5	208.7	138.7	115.3	103.7	96.7	82.7		
PV pumps (floating or surface)	99.9	86.2	81.7	79.4	78.0	75.3	74.4	73.9
Hand pumps (including labour costs)	279.7	199.9	226.5	199.9	183.9	183.9	183.9	183.9
(excluding labour costs)	159.7	79.9	106.5	79.9	63.9	63.9	63.9	63.9

From the table above it can be seen that for shallow wells and low flowrates, solar pumps are economically viable.

For the higher hydraulic loads, the small surface-mounted motor pumps are more economic. However, in selecting a technology, additional factors may need to be considered, including the availability of spare parts and the dependability of fuel supplies for motor pumps and Diesel generators.

Table A 9.4.3. Cost of Pumping Water from Deep Wells, centimes FD/Wh

		HYDRAULIC ENERGY DEMAND, Wh/day							
TECHNOLOGY		200	400	600	800	1000	2000	3000	4000
Submersible pumps (based on petroleum at $ 20/bbl)		388.2	197.1	133.3	101.5	82.4	46.8	37.7	33.2
Wind pumps,	V = 4.5 m/s	151.8	81.8	54.8	46.8	39.8	25.8	21.1	18.8
	4.0	156.8	86.8	63.4	51.8	44.8	30.8	26.1	23.8
	3.5	165.0	95.0	71.7	60.0	53.0	39.0	34.4	32.0
	3.0	179.8	109.7	86.4	74.7	67.7	53.7	49.1	46.7
	2.5	208.7	138.7	115.3	103.7	96.7	82.7		
PV pumps (submersible)		99.9	86.2	81.7	79.4	78.0	75.3	74.4	73.9
Hand pumps (including labour costs)		279.7	199.9	226.5	199.9	183.9	183.9	183.9	183.9
(excluding labour costs)		159.7	79.9	106.5	79.9	63.9	63.9	63.9	63.9

For the deeper wells, the windmill pumps are the most economic option if mean windspeeds at the site are at least 3 m/s. If windspeeds are below this level, submersible photovoltaic pumps are economic up to hydraulic energy loads approaching 1,100 Wh/day.

ANNEX 9.5 THE A AND B SYSTEM FOR BUSES AND MINIBUSES

A 9.5.1. Introduction

The report by Gomez on the transport sector recommends the introduction of a system of operation for the urban buses and minibuses where the fleet is divided into 2 groups, A and B /9.3/. The vehicles in each group run on alternate days.

There are basically two reasons for proposing this measure:

a) There are too many buses and minibuses, even considering the demand during the peak period.

b) The present system of operation is not profitable, particularly during the off-peak periods. The system is uneconomic both for the operators and for the State: too many vehicles are in operation during the off-peak hours.

The average number of passengers carried per vehicle per day is low. Operating costs per passenger are therefore high, and revenue is reduced to a critical level.

The implementation of the A and B system would have a number of advantages, for instance:

- the system would reduce sectoral energy consumption, and thus foreign exchange costs. Operating costs per vehicle would fall, e.g. fuel costs, tyres, lubricating oil, etc.
- it would reduce the work hours for drivers and their assistants.
- Wages for drivers and assistants might be better assured; they might even rise.
- The number of vehicles in operation would be better matched to the demand during the peak hours.
- Fewer vehicles would run during the off-peak periods.

Given the still limited amount of data on the operation of the bus system, it is difficult to estimate the present imbalance between supply and demand during peak hours, and to what extent the A and B system might reduce it.

A more detailed study of the public transport system is needed, based on more precise data concerning the number of buses in operation, and the level of demand during peak periods.

For this reason, the financial and economic analysis of the A and B system presented in the following paragraphs examines solely the impact of the system during the off-peak hours.

It should be stressed, however, that the principal benefits of the A and B system are generated much more by the operation of this system during the off-peak hours than by its operation during the peak hours.

A 9.5.2. Characteristics of the Present System

Information concerning the structure and operation of the urban public transportation system has been gathered from the results of several surveys, and from other available data.

More detailed data is set out in Table 1.4.4. of Chapter 1. The major points can be summarised as follows:

- the number of passengers carried each day is 150,000; 40 % are transported by bus, 60 % by minibus.

- the number of vehicles in service is estimated as 503, of which 40 % are buses.

- the vehicles operate for 10 hours per day, including 4 hours of peak demand.

- 70 % of the traffic takes place at the peak periods.

- The levels of vehicle occupancy are as follows:

  - peak periods 43 %
  - off-peak periods 12 %
  - average occupancy 25 %

A 9.5.3. The A and B System During the Off-Peak Periods

Based on the available data at the present time, the A and B system, operating during the off-peak periods, concerns 30 % of the passengers and 60 % of the vehicle-km travelled.

With the A and B system defined in this way, the rate of occupancy during the peak hours will remain the same, whereas during the off-peak hours it will increase from 12 % to 24 %.

The level of service will therefore be the same for 70 % of the passengers. For the remaining 30 %, the level of service will be marginally reduced.

A 9.5.4. The Cost of Vehicle Operation

Table A 9.5.1. below sets out the estimated costs of operating buses and minibuses in Djibouti-ville, both including and excluding taxes.

Table A 9.5.1. Buses and Minibuses: The Costs of Operation

	Annual Costs per Vehicle (1000 FD 86)			
	market price	%	excluding taxes	%
1. BUSES				
1.1. Fixed costs	2,574	63	2,215	71
1.2. Variable costs	1,540	37	891	29
1.3. Total	4,114	100	3,106	100
2. MINIBUSES				
2.1. Fixed costs	2,054	62	1,819	71
2.2. Variable costs	1,249	38	743	29
2.3. Total	3,303	100	2,562	100

A 9.5.5. The Financial Impact of the A and B System

From Tables 1.4.5 and A 9.5.1., Table A 9.5.2. sets out the principal results of the analysis of the present financial situation of a bus or a minibus owner.

The main conclusions of this analysis can be summarised as follows:

- From a financial perspective, i.e. at market prices, the tariffs which apply at the present time do not cover the operating costs for either a bus or a minibus.
- From an economic perspective, i.e. excluding taxes, costs are still greater than revenue for a bus; for a minibus revenue is marginally greater than costs.
- The real financial revenues (taxes) for the State are less than those which appear in the accounts, considering the fact that the public transport user is practically subsidized.

Table A 9.5.2 Costs and Revenues for a Bus and Minibus Under the Present System of Operation

	FD 84/Passenger			
	market prices		excluding taxes	
	bus	minibus	bus	minibus
a. Costs per passenger transported	46.1	37.6	34.8	29.2
b. Revenue per passenger transported	30.0	30.0	30.0	30.0
c. Costs - revenue per passenger transported	-16.1	- 7.6	- 4.8	+ 0.8

Table A 9.5.3. shows the expected reduction in annual costs for a bus and a minibus under the A and B system. The new system reduces variable costs by 50 %, principally for fuel, tires, and lubricants.

Table A 9.5.3 Costs and Revenues for a Bus and Minibus Under the A and B System of Operation

	FD 86/Passenger			
	market prices		excluding taxes	
	bus	minibus	bus	minibus
a. Costs per passenger transported	40.9	33.3	31.8	26.7
b. Revenue per passenger transported	30.0	30.0	30.0	30.0
c. Costs - revenue per passenger transported	-10.9	-3.3	- 1.8	+ 3.3

The reductions in variable costs shown in Table A 9.5.3. are in fact underestimated because the projected savings in maintenance costs have not been taken into account.

From an economic perspective, the A and B system produces a net saving for the case of the minibus; for a bus, the balance is slightly negative.

To redress the financial balance, assuming the tariff remains the same, it would be necessary to reduce the level of taxes which are now levied.

A 9.5.6. Impact on the National Economy and on Public Finances

Table A 9.5.4 presents the total cost of operating the urban transport system in Djibouti ville, based on the estimates of the costs per vehicle developed above.

Under the present system of operation, total annual costs at market prices are 1,824.4 MFD (1986), of which 597.9 MFD (33 %) is expended for fuel, and 426.2 MFD (23 %) is spent on taxes.

This table also shows the estimated reductions in these costs which would result from the introduction of the A and B system, as well as the smaller reductions in State revenues which would occur over the short term.

Table A 9.5.4 Total Cost of Operating the Urban Transport System in Djibouti ville, and the Impact of the A and B System on the National Economy and Public Finances

(Million FD 86)

	BUS	MINIBUS	TOTAL
1. TOTAL ANNUAL COSTS			
1.1. At market prices	827.2	997.4	1824.4
1.2. Excluding taxes	624.2	773.6	1397.8
2. TOTAL ANNUAL COST OF FUEL			
2.1. At market prices	264.2	333.7	597.9
2.2. Excluding taxes	146.1	193.0	339.0
3. TAXES: ANNUAL TOTAL	202.3	223.9	426.2
3.1. Vehicles	60.9	54.4	115.3
3.2. Registration	10.8	16.9	27.7
3.3. Fuel	118.1	140.7	258.8
3.4. Tyres	11.8	11.0	22.8
3.5. Lubricants	0.7	0.9	1.6
4. REDUCTION IN TOTAL COSTS UNDER THE A AND B SYSTEM			
4.1. At market prices	92.9	113.1	206.0
4.1.1. Fuel	79.3	100.1	179.4
4.1.2. Tyres	12.6	11.8	24.4
4.1.3. Lubricants	1.0	1.2	2.2
4.2. Excluding taxes	53.7	67.4	121.1
4.2.1. Fuel	43.8	57.9	101.7
4.2.2. Tyres	9.1	8.5	17.6
4.2.3. Lubricants	0.8	1.0	1.8
5. DIRECT REDUCTION IN STATE REVENUES	39.2	45.7	84.9

The total annual reductions which might therefore be obtained as a result of the introduction of the A and B system are presented in Table A 9.5.5. overleaf.

Table A 9.5.5 Reductions in Total Costs

		At market prices	Excluding taxes
Present total costs,	MFD/yr	1824.4	1397.8
Total costs (with A + B),	MFD/yr	1618.4	1276.7
Reduction in costs,	MFD/yr	206.0	121.1

A 9.5.7. Conclusions

The conclusions of the analysis of the A and B system set out in the sections above are as follows:

- The proposition is economically viable, since the A and B system produces net savings of 121.1 million FD per year.
- The State should not receive any less revenue since the direct reduction of 84.9 million FD will be equal or less than the indirect revenue which can be expected to be received. Net savings will return to the economy as consumption or investment, and will therefore generate taxes for the State.
- The economic benefits will be permanent once the A and B system is in operation.

ANNEX 9.6 IMPROVED PRODUCTION OF CHARCOAL

The proposed technique is very simple, and does not require any great skill on the part of the charcoal-makers. The procedure consists of the followings steps:

- A pit is dug in a place where the soil is easily worked.
- Six air pipes are slanted into the pit. Three pipes to let air in, and three to permit smoke to escape are sufficient for a pit with a volume of several cubic metres.
- A log is placed in the bottom of the pit to permit air to circulate under the wood. Flammable material used to start the fire is then added in the centre of the pit.
- The wood to be carbonized is then loaded into the pit which should be filled to the level of the soil. A narrow vertical channel is left in the centre of the pile for lighting the fire.
- The fire is started. If the wood dry, as in Djibouti, this step takes only a few minutes. When the fire is well established in the centre of the charge, the pit is covered with sheets of corrugated iron and then sealed with earth.
- Chimneys are placed in every other pipe.
- When the air flow is established, dense grey smoke will issue from the chimneys.
- When embers can be seen through the air inlet pipes, the position of the inlet pipes and the chimneys is reversed.
- The carbonization process is complete when embers can be seen through the new air inlets, and the smoke from the pit is light and has a bluish tinge. The change in the appearance of the smoke is an indication that all volatile matter has been driven off, and that it is now the charcoal which is burning.
- The chimneys are then removed and the pit is completely sealed.
- Care must be taken to prevent any air from entering since this will sustain the combustion of the charcoal, and the amount of charcoal produced will therefore be lower.

- When the corrugated iron is cold, the pit is uncovered and the charcoal is removed. Because of the thermal insulation provided by the soil, the cooling period is fairly long: about 36 hours.

This technique has several advantages: it is not expensive; it produces much more charcoal than the open fire method, and it is not difficult to carry out.

Moreover, the carbonization is very rapid--4 to 6 hours if the wood is very dry, the exact time depending on the diameter of the wood--and the procedure does not, therefore, take up too much of the charcoal-maker's time.

The complete cycle of charging and discharging takes about 48 hours; a typical schedule might be as follows:

Day 1	- early morning	- charging, igniting
	- towards midday or early afternoon	- sealed, extinguished
	- evening	- cooling
Day 2	-	- cooling
Day 3	- early morning	- discharging, bagging.

The technique is so effective that one might be concerned that the production of charcoal could rise to the point where the consumption of wood might actually increase. Obviously, it is not the intention that an improvement in the efficiency of charcoal production should lead to an increased exploitation of biomass resources--the very opposite effect of what was intended.

However, this possibility appears to be remote since the demand for charcoal is stable, and seems unlikely to grow excessively given the very specific uses of this fuel.

It is therefore recommended that the program of demonstration and training in the use of the technique, which has already begun, be continued with the aim of both reducing the consumption of wood and improving the standard of living of the charcoal-makers.

Economic Analysis

Table A 9.6.1 presents a brief economic analysis of the improved technique, including the costs and benefits in comparison with those of the traditional open fire method.

The calculation assumes a pit with a volume of 3 m3, requiring 3 corrugated iron sheets for the cover, 1.5 sheets for the 3 chimneys, and 1.5 sheets for the 6 air inlet pipes. Several hypotheses are examined:

- Three hypotheses concern the amount of wood carbonized: 400, 500, and 600 kg; 500 kg is probably the most reasonable assumption.

- Two hypotheses concern the amount of charcoal produced from a charge of wood:

  - For the open fire, efficiencies of 17 % and 12 % by weight are assumed. The higher figure was measured at Tadjourah; the lower figure is considered to be more typical.

  - For the covered pit technique, efficiencies of 30 % and 25 % are assumed. The higher figure was obtained during tests of the technique conducted by ISERST; the lower figure should be easily attainable even by charcoal-makers with little or no experience with the method.

- Two cases are examined for the initial investment:

  - 6 corrugated iron sheets at 1,000 FD each (0.5 mm thick)
  - 6 sheets at 1,500 FD each (0.8 mm thick)

Whichever figures are used, one finds that the payback time, defined in terms of the number of carbonizations, is very short.

The worst case is 11 carbonizations for the situation where the thicker sheets are used and the lower efficiency is assumed.

A series of 20 carbonizations produces a revenue significantly higher than the initial investment.

The thinner corrugated iron sheets (0.5 mm) should last for at least a season of 20 to 30 carbonizations. The thicker sheets (0.8 mm) would obviously last considerably longer.

Table A9.6.1 Comparison of Techniques for the Production of Charcoal

TECHNIQUE	MASS OF WOOD, KG	EFFICIENCY (MASS) %	EFFICIENCY (ENERGY) %	CHARCOAL PRODUCED, KG	NUMBERS OF SACKS	INVESTMENT, FD,*	REVENUE (100FD/SACK)	PAYBACK TIME IN NUMBER OF CARBONIZATIONS 12%	PAYBACK TIME IN NUMBER OF CARBONIZATIONS 17%	REVENUE FROM 20 RUNS	ADDITIONAL REVENUE FROM IMPROVED METHOD (a)	ADDITIONAL REVENUE FROM IMPROVED METHOD (b)
OPEN FIRE LOW EFFICIENCY	400 500 600	12	21	48 60 72	1,2 1,5 1,8	0	1 200 1 500 1 800			24 000 30 000 36 000		
HIGHER EFFICIENCY	400 500 600	17	29	68 85 102	1,7 2,1 2,5	0	1 700 2 100 2 500			34 000 42 000 50 000		
PIT METHOD GOOD OPERATION	400	30	50	120	3	6 000 9 000	3 000	3,3 5,3	4,6 6,9	54 000 51 000	30 000 27 000	20 000 17 000
	500	30	50	150	3,75	6 000 9 000	3 750	2,6 4	3,6 5,5	69 000 66 000	39 000 36 000	27 000 24 000
	600	30	50	180	4,5	6 000 9 000	4 500	2,2 3,3	3 4,5	84 000 81 000	48 000 45 000	34 000 31 000
AVERAGE OPERATION	400	25	43	100	2,5	6 000 9 000	2 500	4,6 6,9	7,5 11,2	44 000 41 000	20 000 17 000	10 000 7 000
	500	25	43	125	3,1	6 000 9 000	3 100	3,7 5,6	6 9	56 000 53 000	26 000 23 000	14 000 11 000
	600	25	43	150	3,75	6 000 9 000	3 750	3 4,6	4,8 7,2	69 000 66 000	33 000 30 000	19 000 16 000

* light corrugated sheets at 1000 FD each,and heavier sheets at 1500 FD each.

CHAPTER 10

RECAPITULATION, CONCLUSIONS, AND RECOMMENDATIONS

Both of the scenarios studied in this report, the reference scenario and the growth scenario, forecast significant increases in national energy demand by the year 2000.

Djibouti can respond in 2 different ways to this increasing demand for energy:

- The country can react to the evolving demand, responding as the need arises on an ad hoc basis,
- or the country can manage the evolution of energy demand, by anticipating its growth and by planning for its impact.

For several years, the Government of Djibouti has adopted the second course of action. This approach will permit the country to manage its energy future effectively, and to avoid being at the mercy of a seemingly capricious energy supply and demand system.

The analyses and studies conducted at ISERST have confirmed the validity of the energy policies adopted by the Government. This report recommends the strengthening of present energy sector activities through the implementation of a series of priority energy sector development projects which are intended to assure the energy future of the country.

This chapter presents a summary of the analyses conducted during the course of this study, as well as the principal results and findings. It also sets out the conclusions reached and recommends actions and projects to be implemented over the short and medium term.

10.1 RECAPITULATION

10.1.1. Accomplishments of the Study

In addition to the analyses and the energy sector modeling, a number of sectoral studies were conducted where data pertaining to energy supply and demand were either non-existent or inadequate. These studies concerned, primarily, the biomass energy system, the transport sector, and electricity.

In parallel with these studies, a large amount of pertinent data and information was collected and organized into a database, and the MEDEE-S computer model was adapted to the case of Djibouti.

10.1.1.1 Biomass Energy

Biomass energy provides more than 13 % of national energy requirements, and plays an important role in the context of Djibouti's energy independence. However, the structure and the dynamics of the biomass energy supply and demand system have not been adequately studied.

The brief study that was conducted during August and September, 1986, shed some light on the situation, and identified some of the principal links in the chain of production and consumption. For instance:

- In general, it is dead wood which is collected. However, some wood is cut from standing trees.

- The collection of wood from the areas surrounding the settlements is traditionally the work of the women. The distances travelled to find wood are increasing, evidence of the continuing desertification.

- The wood is carried to the towns and villages by truck, dhow, camel, and ass.

- The wood stoves used are the 3-stone type, which are very inefficient.

- The production of charcoal, commonly made using an open fire, is also very inefficient.

The study concluded with a survey of household energy consumption by District, and by the demonstration at ISERST of improved cookstoves and a more efficient technique for producing charcoal.

10.1.1.2 Transportation

Two aspects of the transportation sector were studied in particular detail: the urban public transport system, and the system of vehicle taxation.

The study of the urban transport system: the number of buses and minibuses in service, their schedules, the number of passengers etc., confirmed that there are too many vehicles in service given the demand. This excess of buses and minibuses results in high levels of fuel consumption per vehicle.

To improve this situation two complementary actions are proposed:

- The division of the fleet of vehicles into two groups, each of which operates on alternate days. This proposal has the support of the transport workers union, and could in principle be implemented in the very near future.

- The implementation of a differential system of vehicle taxation where vehicles are taxed in proportion to their power. This measure is aimed at limiting the number of powerful all-terrain vehicles which are often only used for short trips in the urban areas.

10.1.1.3 Electricity Tariffs

The structure of electricity tariffs significantly influences both the level and the pattern of electricity consumption.

The tariffs now in effect take account of certain social and political considerations, and encourage the electrification of the low income households. The price of electricity charged to some consumers, therefore, does not always reflect the real cost of providing them with electricity.

A study of Electricité de Djibouti was conducted which examined several aspects of the agency's operations including production, distribution, management, and its tariffs. Following this study, a tariff structure based on the marginal costs of production was formulated and proposed.

The proposed system of tariffs favours the mid range voltage subscribers more than the low voltage subscribers, and the tariffs now need to be revised to take account of certain social and economic considerations.

10.1.1.4 Development of an Energy Database

In parallel with the studies outlined above, discussions with senior personnel in different agencies and businesses involved with either the production, supply, or the consumption of energy, took place with the aim of collecting appropriate data and information on energy, and identifying the major issues and the projects planned in the short and mid term.

These discussions resulted in the establishment of a database essential for the analysis of energy supply and demand, and for the development of a model of the energy sector.

10.1.1.5 Adaptation of the MEDEE-S Model

The MEDEE-S computer program was chosen as the most effective means to model the structure of energy demand.

Several modules were added or rewritten so as to adapt the model to the particular structure and form of the situation in Djibouti. For instance, a module on water pumping was added to the model.

The definition and organization of the data needed by the MEDEE-S model required a considerable amount of work in order to disaggregate and structure the different sectors and sub-sectors.

The residential sector was modeled in detail, largely as a result of the data furnished by the Direction Nationale de la Statistique, which included questions related to energy consumption into a DINAS survey of household economics.

10.1.2 The Principal Results

The integration of the results of the different sectoral studies, the development of the energy database, and the adaptation of the MEDEE-S model, led finally to the development of a map of the energy situation in Djibouti, and then to the projection and evaluation of its future structure according to different socio-economic scenarios.

The principal results of these calculations and projections are summarized in the paragraphs which follow.

10.1.2.1 The Energy Balance for 1985

The total consumption of energy in Djibouti in 1985 was close to 71,300 TPE, equivalent to a consumption of 0.166 TPE per capita.

The distribution of consumption by sector and by energy type is shown below:

Sector		Energy	
Industry, agriculture	5.3%	Wood, charcoal	15.5%
Transportation	39.8%	Petroleum fuels	67.6%
Services	17.6%	Electricity	16.9%
Residential	37.3%		

10.1.2.2 The Demand Scenarios

Two scenarios related to the future demand for energy were studied--a reference scenario, modeled on the present economic situation, and a scenario which modeled a higher rate of economic growth.

The projected increase in energy demand in the year 2000 is 63 % for the first scenario, and close to 100 % for the second. The distribution by source of energy and by sectoral consumption is shown in Tables 10.1.1 and 10.1.2 respectively

Table 10.1.1 Evolution of Energy Demand by Source, TPE

	Present Situation (1985)	Scenario (to year 2000)	
		Reference	High growth
LPG	623	990	2,346
Kerosene	10,096	19,739	21,893
Gasoline	10,613	12,223	15,815
Diesel fuel	22,425	39,325	50,300
Jet fuel	4,506	8,196	9,462
Sub total	48,263	80,473	99,816
Electricity	12,018	20,263	26,655
Wood	10,175	13,908	8,150
Charcoal	842	1,691	1,562
Non-conventional	-	-	4,391
TOTAL	71,298	116,335	140,574

Table 10.1.2   Evolution of Energy Demand by Sector, TPE

	Present Situation (1985)	Scenario (to year 2000)	
		Reference	High growth
Industry and construction	3,597	7,913	10,247
Agriculture, fishing	189	327	430
Transportation	28,393	44,888	61,421
Services	12,578	18,168	21,325
Residential	26,541	45,039	47,052
TOTAL	71,298	116,335	140,575

10.2 CONCLUSION

From an assessment of the present energy situation in Djibouti, and an analysis of the demand projections made by the model, a number of conclusions can be drawn which are summarized below.

10.2.1 National energy planning remains essential for the formulation of effective energy policy by the Government.

10.2.2 The major development programs now underway in the energy sector are confirmed as being priorities. These programs concern in particular:

- the expansion of the programs supporting the more widespread use of photovoltaic pumps and wind pumps.
- the development and exploitation of geothermal resources.
- the promotion of energy conservation measures in all sectors of the economy.
- the dissemination of improved woodstoves, and of a more efficient technique for the production of charcoal.
- improvements to the electricity generating system.

10.2.3 The present excess generating capacity of EdD provides a margin of several years before policy decisions concerning the installation of future electricity generating systems need to be taken. These decisions, once taken, will commit the country to a long period of costly investments in the energy sector.

This grace period should be taken advantage of for completing the technical and economic analyses now underway, and for making available as much relevant information and data as possible for the important decisions which must be taken in the near future.

10.2.4 At least until the year 2000, the major part of the national energy supply will be provided by imported petroleum.

It is expected that world petroleum supplies will continue to be available during this period, although one cannot discount the possibility of geo-political problems which might occasionally disrupt supply.

The price of petroleum needs to be monitored very closely since it strongly influences the economics of many of the projects and initiatives proposed in this study.

10.3 RECOMMENDATIONS

The work performed during this study has made an essential contribution to the development of a coherent national energy policy.

However, there is much that remains to be accomplished. This study recommends a number of actions to extend or complete work already commenced, and the implementation of several new projects and studies.

10.3.1 Continuation of the Energy Planning Initiatives

The energy planning work so far accomplished is only the first step in a comprehensive program of study and analysis of the energy sector.

It is necessary to continue and support this effort by strengthening the present team of analysts at ISERST and the Energy Service, by the addition of energy analysts, economists, and managers.

The mission of the energy planning team will be to bring up to date the data and information collected and organized by this study, to extend the database where possible, to direct sectoral studies where appropriate, and to broaden the application of the MEDEE-S model in such a way that policy-makers have available to them all the information and data necessary for effective energy planning and decision-making.

10.3.2 The Development of Training Programs

The proper training of technicians and personnel is essential for the efficient development of energy resources and the effective management of the energy sector.

There are numerous examples in other countries where inadequately trained personnel have jeopardised the success of energy sector development projects.

In Djibouti, training has always been considered a priority, and many managers, engineers, and technicians have participated in training programs not only in Djibouti itself, but also overseas particularly in France and the United States.

It is recommended that this policy be continued, and that training be in fact expanded over the next few years.

The proposal to create a professional training centre for the personnel of EdD is an excellent one, and should be fully supported.

It is also recommended that the training programs conducted in Djibouti be expanded and extended to include other personnel in the various services and agencies working in areas related to energy production, distribution, and consumption.

10.3.3 Expansion of the Energy Conservation Programs

In numerous instances in Djibouti, much more energy is consumed than is necessary either because of negligence or because of lack of information. Taken together, these potential savings amount to a significant energy resource.

The exploitation of this resource is important both for the State, and for the individual energy consumer. For the State, the advantages include reduced foreign exchange costs, reduced electricity generating capacity over the longer term, and savings in Government recurrent costs. For the consumer, the major advantage is a significant reduction in energy bills.

Several energy conservation techniques have been designed and tested. The payback times for these measures are typically very short: less than a year.

It is therefore recommended that these initiatives should be continued and expanded, particularly in the residential and service sectors, and in public lighting and transportation. These initiatives are discussed in greater detail in the sections which follow.

10.3.3.1 The Residential and Service Sectors

a) Air Conditioning

At the present time there are no building codes or standards which require the installation of thermal insulation in new building construction.

The poor thermal characteristics of the buildings means that additional air conditioners need to be installed. The result is an excessive consumption of electricity, and very high electricity bills.

A number of measures can be taken to encourage or require the use of thermal insulation in building construction:

- technical assistance and advise can be offered to designers and architects.

- technical assistance regarding thermal insulation can be offered on site.

- building codes and standards requiring the use of insulation can be legislated and imposed.

These actions are underway, and it is essential that they continue to be supported and strengthened.

b) Refrigeration

Refrigerators account for the second highest component of household electricity consumption. The reasons for this high consumption have been discussed in several sections of this report: the refrigerators are inadequately insulated and they are often placed outside the home in a hot courtyard, generally in the sun.

ISERST and the Energy Service have proposed a program to add insulation to 11,000 refigerators now in service. This program would be financed by a fund of 89 million FD, accrued by EdD when the price of petroleum fell at the end of 1985.

This proposal has several major benefits:

- energy savings
- reduced electricity bills
- the creation of employment
- reduced imports of petroleum fuels.

It is recommended that every effort be made to implement this program, and bring it to a successful conclusion. This initiative could, in fact, serve as a model for other efforts to use energy more efficiently, both in Djibouti and in other countries facing similar problems.

c) Lighting

The program of refrigerator insulation outlined above includes a second complementary action which aims to replace 15,000 incandescent bulbs with fluorescent lamps in the residential sector.

It is also recommended that this program be extended to include the service sector, although in some instances incandescent or natural lighting may be preferred.

The replacement of the lamps in the corridors of the Cité Ministérielle with high efficiency compact lamps, or the retrofitting of skylights in the Ambouli dispensary, are measures that could be replicated in other buildings.

d) Ventilation

In Djibouti, perhaps more than elsewhere, ventilation plays an essential role in thermal comfort. In spite of the extreme temperatures, the circulation of air brings a degree of relative coolness.

The wind regime is favorable for the use of natural ventilation in buildings; for more than 9 months of the year it blows from the sea and is relatively cool.

Several experiments have confirmed the advantages of natural ventilation in Djibouti. A number of building projects incorporating the technique are now either underway or are being designed.

It is essential to encourage this mode of ventilation which relies on wall openings which are low on the windward side, and high on the leeward.

The cost of the work is minimal, and significantly improves the level of comfort inside the building without recourse to ceiling fans or wall fans.

e) Architectural Design

The architecture of a building is in large measure responsible for its interior comfort (or discomfort), and for the amount of energy the building will consume.

There are several basic rules concerning the design of buildings in hot climates with which every architect should be familiar. These rules concern:

- the shading of the walls of the building
- the adequate ventilation of the interior
- the reduction of thermal losses through the building envelope when the interior is air conditioned.

These basic concepts can be combined in many ways. For instance, the architect can set the building orientation, arrange the disposition of the rooms, fix the extension of the roof and the location of shade trees, and decide on the degree of thermal insulation to be installed.

In collaboration with the Bureau of Urban Planning and Housing and several other Government services, ISERST has designed and constructed 3 prototype buildings. These buildings incorporate many of the measures recommended for energy efficient and bioclimatic building design, and they have succeeded in generating a good deal of interest among local architects and builders.

It is recommended that this type of building design and concept be promoted in Djibouti to the point where bioclimatic design becomes the de facto norm.

f) Cooking

Outside of Djibouti ville and the larger towns, cooking continues to be done using the traditional 3-stone fire.

As this study has shown, this method of cooking consumes excessive amounts of wood, principally because of the high thermal losses from the fire and the cooking pot.

Improved clay cookstoves, several of which have already been tested by ISERST in four schools in the north, would seem to be appropriate given the mode of cooking in Djibouti and the availability of the necessary materials.

Consequently, after evaluation and confirmation of the performance and acceptability of the new stoves, it is recommended that a program to encourage the widespread use of the stoves be launched. This program would employ selected women at the village level who would be responsible for promoting the stoves in their village.

10.3.3.2 Transportation

a) Buses and Minibuses

As discussed in this report, studies of the transport sector have shown that there are too many buses and minibuses in service. The resulting competition for passengers leads to excessive fuel consumption by the vehicles because of poor maintenance, the constant chase for passengers, the low level of vehicle occupancy, the habit of leaving engines idling, etc.

In order to improve this situation, it is recommended that the proposal outlined in section 10.1.1.2 be adopted, i.e. to divide the fleet of buses and minibuses into two groups, A and B, each group running on alternate days outside of the hours of peak passenger demand.

This arrangement would:

- raise the level of vehicle occupancy,
- improve the general condition of the vehicles,
- provide better working conditions for the drivers,
- reduce the number of traffic jams,
- and finally, reduce the consumption of fuel.

b) Automobiles

The average fuel consumption of a vehicle in Djibouti is generally much higher than the figures given by the manufacturers. There are several reasons why this is the case.

- the high ambient temperatures prevent adequate engine cooling which reduces the efficiency of the engine.
- the use of the vehicle air conditioner imposes an additional and significant load on the engine.

- air filters are not cleaned regularly. This is essential given the amount of dust inducted while driving, particularly outside of Djibouti ville.
- the carburettor system is poorly regulated.

The colour of the vehicle exhaust fumes seen in Djibouti is proof enough of the poor regulation of the engines. The dissemination of appropriate information, or perhaps legislation, is needed to address these problems.

A further point concerns the increasing number of all-terrain vehicles being purchased. These vehicles, which are relatively powerful, consume significantly more fuel than the typical small car which is not only lighter but more aerodynamic.

While the use of all-terrain vehicles is a necessity for travelling in the interior of the country, their use in and around Djibouti ville, where 90 % of the travelling takes place, is unnecessary. The result is an excessive consumption of gasoline and Diesel fuel.

The same tendency can be seen when one looks at the vehicles in service in Government ministries and agencies. The short distances travelled, and brief amount of time spent in the vehicles, do not justify the acquisition of such powerful vehicles.

Small cars are almost as comfortable as the larger vehicles, and their handling and manoeuvrability are often superior. The fuel consumption of the smaller cars is typically between 8 and 9 litres/100 km in urban driving; the all-terrain vehicles consume between 13 and 15 litres of fuel to cover the same distance.

It is therefore recommended that the Government take appropriate measures to require the purchase of small cars for the public service agencies, and to encourage the purchase of small cars in Djibouti by the introduction of a system of differential vehicle taxation.

10.3.3.3 The Industrial Sector

This sector is characterized by a certain heterogeneity which makes generalizations difficult. Apart from perhaps shifting the hours of production away from those times of the day when household electricity demand is at its peak, no general measures for reducing the consumption of energy are proposed.

Certain specific actions, such as the preheating of water using solar collectors at the Dairy, might however be considered on an individual basis.

10.3.3.4 Agriculture and Fishing

The agricultural sector is developing rapidly based on small holdings run by families or cooperatives. Apart from water pumping, the energy used is either human or provided by animals. Additional sources of energy, and measures to use energy more efficiently, are both required by this sector.

Concerning the production of charcoal, major improvements are possible which will save substantial amounts of wood. Recent demonstrations of an improved charcoal-making technique carried out by ISERST in the north of the country showed convincingly that the efficiency of production can be increased by 100 %.

The strong interest of the charcoal-makers in the region of Randa and Adailou underscores the advantages of the covered pit technique in comparison with the traditional method which uses an open fire. The adoption of the covered pit technique in all regions of the country should therefore be encouraged.

With regard to fishing, a number of energy conservation measures are being implemented. The wooden hulls of the boats are being replaced by lighter plastic hulls, and the management of fish stocks is being studied with a view to reducing the amount of refrigeration and freezing required. It is recommended that these initiatives be encouraged and fully supported.

10.3.3.5 Public Lighting

The main roads of Djibouti are not adequately illuminated. This reduces nighttime visibility for drivers, and contributes to the relatively high rate of accidents at night.

To improve this situation, two alternative actions are possible:

- The power of the mercury vapour lamps now in use could be increased,
- The mercury lamps could be replaced by sodium lamps, which are more expensive, but which give more than twice the illumination for the same electricity consumption.

It is recommended that high pressaure sodium lamps be installed along the main roads in order to improve the level of street lighting without increasing the consumption of electricity.

10.3.4 Development of Indigenous Sources of Energy

10.3.4.1 Solar Energy

High levels of insolation are found in Djibouti. Moreover, the solar resource is dependable and exhibits little variation throughout the year. Solar energy is therefore a resource which should be exploited in Djibouti, particularly for water pumping and for refrigeration.

At the end of 1986, there were about 10 photovoltaic pumps in operation. During 1987, it is planned that another 15 pumps will be installed. This water pumping technology, as has been shown in the preceding chapters, is well adapted for use in the more remote parts of the country, and can make a significant contribution to rural development and to the quality of life in these areas.

It is therefore recommended that the program of photovoltaic pump installation be continued and extended.

10.3.4.2 Wind Energy

Many regions of Djibouti have mean windspeeds close to 4 m/s. The prevailing wind is from the east for 9 months of the year. A mean windspeed of 4 m/s is high enough to make wind pumps a viable option for pumping water, but is generally considered too low for the generation of electricity using wind turbines.

At the beginning of 1987, a major initiative was launched by ISERST with the help of the French Army to rehabilitate several of the large wind pumps installed in Djibouti. Three wind pumps were dismantled, repaired, repainted, and erected on new sites.

All the windpumps in Djibouti, about 10 in all, are now operating satisfactorily, and demonstrate the potential of this technology to play an important role in water supply and rural development.

It is therefore recommended that the present program be continued and extended to the more remote areas of the country where both wind pumps and photovoltaic pumps can make an important contribution to rural development.

10.3.4.3 Geothermal Energy

The exploratory well drilled near Lac Assal in 1975 showed sub-surface temperatures which gave high hopes for the future development of geothermal energy in Djibouti.

The program of extended exploration in the region of Hanlé, which is now underway, should confirm the potential of geothermal energy and, it is hoped, lead to the exploitation of this resource for the generation of base load electricity.

The incremental exploitation of geothermal energy in Djibouti will produce a welcome degree of energy independence, as well as a significant reduction in the cost to the nation of importing petroleum.

It is therefore highly recommended that the present exploratory program be fully supported and, if successful, followed by the construction of geothermal power generation systems which could supply the base of the electricity demand.

10.3.5 Completion of the Studies on Energy Supply, Production, and Tariffs

The determination of appropriate energy prices depends on a complex calculation which should take into account the supply system, the method of production, and the system of distribution.

Each of the links in this chain needs to be studied individually in order to determine the possibility of reducing the final cost of energy. These studies concern principally wood, charcoal, petroleum fuels, and electricity.

10.3.5.1 Wood and Charcoal

In addition to actions aimed at improving the efficiency of woodstoves and the production of charcoal, which are described in paragraphs 10.3.3.1 and 10.3.3.4 respectively, a comprehensive study of the biomass resource base is an urgent necessity, if this vital resource is to be properly managed.

Although in certain regions of the country the collection of fuelwood by the dispersed rural populations has little impact on the local environment, in other regions the collection of wood is more intensive and contributes to the desertification of the area.

It is necessary to map the availability of wood resources, and to show those critical zones where urgent action may be required, including efforts to reforest these areas.

10.3.5.2 Petroleum Fuels

The setting of petroleum fuel prices is the responsibility of EPH. Prices are set taking account of numerous cost components including the world price of oil, freight charges, taxes and surtaxes, profit margins, as well as considerations which are more social and political than economic.

A study of the petroleum fuel supply system will soon be completed by analysts provided by the UNDP. This study should propose a number of measures aimed at reducing the price of petroleum fuels in Djibouti.

The UNDP study should now be completed by the pre-feasibility analysis of the proposal to construct a small oil refinery in the port. This refinery might supply petroleum fuels not only to Djibouti but also to neighbouring countries.

10.3.5.3 Electricity

The relatively small power system does not permit Djibouti to take advantage of the economies of scale and of production demonstrated by large power generation units.

The Diesel generators now in service, for example, are relatively expensive to operate both in terms of fuel consumption and maintenance. The cost of production per unit of electricity is therefore high.

In order to try to reduce the price of electricity, two studies are considered essential.

The first study concerns the type of fuel used by the generators. At the present time, the fuel used is a lighter grade of fuel oil with a viscosity of 600 seconds. However, it appears that the generators could use a heavier grade of fuel oil with a viscosity of 1,500 seconds. This fuel is less expensive.

However, the use of the more viscous fuel will require certain modifications to the system of power generation including the installation of fuel preheaters. In addition, the lifetime of the engines is somewhat reduced, and the cost of maintenance is expected to rise.

It is therefore recommended that an economic and financial analysis of this fuel substitution be performed so that the appropriate decision can be made.

The second study concerns the system used to cool the Diesel generators. At the present time, the generators are air-cooled, but air temperatures in the summer can rise to more than 45 °C in Djibouti.

Since the temperature of the sea is relatively constant and is only about 32 °C, even in the summer, it has been proposed that sea water could be pumped through a heat exchanger which would produce cooler air for cooling the engines. More effective cooling will increase the efficiency of the engines.

A technical and economic analysis of this proposal should be conducted.

Finally, the study of electricity tariffs carried out as a part of this energy planning work should be completed by taking into account certain social and political considerations that have a bearing on the structure of the tariff system to be imposed. These considerations have to do primarily with the tariffs for the low income sectors of the population.

10.4 THE RECOMMENDED PROJECTS

The different actions undertaken as part of this work: data collection, sectoral analysis, modeling of energy demand, and the forecasting of future demand, have lead to the formulation of a number of energy sector development projects for which funding will be solicited from the different donor agencies.

These projects bring together the recommendations set out in this chapter. The projects are arranged in 4 groups which, in effect, represent the principal components of the Government's energy policy, namely:

- The development of institutional capacity.

- The strengthening of programs in demand management and energy conservation.

- The exploitation of indigenous sources of energy.

- The reduction in the cost of production and distribution.

LIST OF PROJECTS

I. INSTITUTIONAL DEVELOPMENT

Project N° 1) Development of the Technology Section of ISERST and the creation of an Energy Planning Group.

Project N° 2) Assistance to the Energy Service.

Project N° 3) Technical assistance to the Public Hydrocarbon Establishment.

Project N° 4) Technical assistance for the Training Centre of Electricité de Djibouti.

II. SUPPORT FOR PROGRAMS IN DEMAND MANAGEMENT AND ENERGY CONSERVATION

Project N° 5) Support for the investment fund for energy conservation.

Project N° 6) Energy conservation in the residential sector.

Project N° 7) Improvement of the efficiency of energy use in public buildings.

Project N° 8) Construction of prototype bioclimatic buildings.

Project N° 9) Promotion of improved cookstoves.

Project N°10) Formulation of a traffic plan for Djibouti ville.

Project N°11) Construction of a maintenance centre for buses and minibuses.

Project N°12) Improvement of the efficiency of public lighting.

Project N°13) Training of refrigeration engineers and technical assistance relating to refrigeration systems.

III. DEVELOPMENT OF INDIGENOUS SOURCES OF ENERGY

Project N°14) Expansion of the wind pump program.

Project N°15) Expansion of the photovoltaic pump program.

Project N°16) Design and construction of a prototype solar cooker.

Project N°17) Exploitation of geothermal energy for electrical power generation.

Project N°18) Improvement of the efficiency of charcoal production.

IV. STUDIES RELATED TO REDUCING THE COST OF ENERGY PRODUCTION AND DISTRIBUTION

Project N°19) Study of the forest resource base.

Project N°20) Feasibility study of sea water cooling of Diesel generators.

Project N°21) Study of waste heat recovery systems at the Boulaos power station.

Project N°22) Feasibility study of a petroleum refinery in Djibouti.