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Madagascar: Issues and Options in the Energy Sector

January 1987

Report of the Joint UNDP/World Bank Energy Sector Assessment Program

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MADAGASCAR

ISSUES AND OPTIONS IN THE ENERGY SECTOR

JANUARY 1987

ABSTRACT

Madagascar's main energy problems are a growing fuelwood crisis resulting from overutilization of the forest resources which provide 80% of its final energy consumption, mainly for cooking, and the country's total dependence on high-cost petroleum imports. In addition, there is a lack of coordination of overall energy operations and policies.

The most pressing issues are related to more efficient exploitation and utilization of existing woody biomass and hydropower resources, and improvement of the existing energy infrastructure in the form of power plant, transmission and distribution facilities and the Toamasina petroleum refinery. The most attractive option for increasing woodfuel supply in the next five years or so is to upgrade traditional charcoaling efficiency and utilize forest residues and non-commercial grade timber such as Haut Mangoro pine smallwood, sawmill wastes and logging residues. Demand-side options include commercial trials of improved wood- and charcoal-burning metal stoves, as well as more efficient kerosene stoves and electric rice cookers. With reinforced and expanded power distribution, the rice cookers would utilize part of the large surplus hydroelectric capacity. Rehabilitation of the petroleum refinery will improve middle distillate yields, thus reducing the need for corresponding imports.

With respect to energy pricing, electricity rates and tariffs in particular need to be rationalized to ensure consistency with economic costs and the financial needs of Madagascar's power utility. There is an urgent need to establish and develop a single effective national energy planning agency while strengthening management and investment programming at the subsector level.

ABBREVIATIONS AND ACRONYMS

adb	air dried basis
BEICIP	Bureau d'Etudes Industrielles et de Cooperation de l'Institut Francais du Petrole
BP	British Petroleum
bpd	barrels per day
CCCE	Caisse Centrale de Cooperation Economique (of France)
c.i.f.	cost, insurance and freight
CIMA	Cimenterie de Amboanio
cm	centimeter
CSP	Conseil Superior du Plan
CSR	Conseil Supreme de la Revolution
DEF	Fishery and Forestry Department
DGP	Directorate General of the Plan
EAR	Estimated Additional Resources
EDF	Electricite de France
EIB	European Investment Bank
ESMAP	Energy Sector Management Assistance Program
FAO	Food and Agriculture Organization
FF	French Francs
FMG	Malagasy Franc
f.o.b.	free on board
GDP	Gross Domestic Product
gms	grams
IAEA	International Atomic Energy Agency
ICS	Interconnected System
IDA	International Development Association
IMI	Malagasy Institute for Innovation
JIRAMA	Malagasy Electricity and Water Corporation
kgoe	kilograms of oil equivalent
LRMC	Long Run Marginal Cost
mai	mean annual increment
mcwb	moisture content wet basis
MES	Ministry of Higher Education
MIEM	Ministry of Industry, Energy and Mines
MPAEF	Ministry of Animal Production, Fisheries and Forests
MRSTD	Ministry of Scientific Research and Technology for Development
MPARA	Ministry of Agricultural Production and Agrarian Reform
od	oven dry basis
OMNIS	National Military Office for Strategic Industries
RAR	Reasonably Assured Resources
SOMAGI	Societe Malgache de Gestion Informatique
SOLIMA	Malagasy Petroleum Refinery Company
SOMLAC	Malagasy Agricultural Association
SR	Speculation Resources
SRMC	Short Run Marginal Cost
toe	tonnes of oil equivalent
tpy	tonnes per year
twe	tonnes of wood equivalent
UN	United Nations
UNDP	United Nations Development Programme

CURRENCY EQUIVALENTS

Currency Unit	=	Malagasy Franc (FMG)
US$1	=	FMG625 a/
US$1	=	French Francs 9 a/

MEASUREMENTS

Bbl	Barrel of oil 42 US gallons; 35 imperial gallons	= 0.15899 cubic meter;
BTU	British Thermal Unit	= 0.252 kilocalories
CF	cubic feet	= 0.02832 cubic meter
Gal	gallon	= 3.7853 liter
GWh	gigawatt-hour	= 1,000,000 kilowatt-hours (kWh)
K(k)	kilo	= 1,000 grams
Km	kilometer	= 0.62 mile = 1,000 meters
kV	kilovolt	= 1,000 volts
kWh	kilowatt hour	= 1,000 watt hours
MVA	megavolt ampere	= 1,000 kilovolt amperes
MW	megawatt	= 1,000 kilowatt (kW)
MWh	megawatt hour	= 1,000 kilowatt hours
toe	tonne of oil equivalent	= 39.68 million BTU
twe	tonne of wood equivalent b/	= 0.32 toe

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a/ Exchange rates as of October, 1984. These are the rates used in the report unless stated otherwise. The Madagascar fiscal year runs from January 1 to December 31.

b/ At 25% moisture content wet basis (mcwb) per unit weight.

ENERGY CONVERSION FACTORS

Fuels	Million kcal per unit	TOE per physical unit
Liquid fuels (tonne)		
Crude oil	10.00	1.00
LPG	11.00	1.10
Avgas	10.50	1.05
Gasoline	10.50	1.05
Kerosene	10.30	1.03
Jet fuel	10.30	1.03
Gas oil	10.20	1.02
Fuel oil	9.70	0.97
Electricity at end use (MWh)	0.86	0.086
Coal (tonne)	6.40	0.64
Fuelwood (tonne at 25% mcwb)	3.20	0.32
Charcoal (tonne at 10% mcwb)	6.90	0.69

1 kcal = 3.968 BTU
1 kcal = 4.19 kilojoules
1 toe = 10.0 million kcal = 39.68 million BTU = 41.9 million kilojoules = 3.1 twe
1 toe = 3,922 kWh on thermal replacement basis
tonne (t) = metric ton = 1,000 kilogram (kg) = 2,204.6 pound (lb)

This report is based on the findings of an energy assessment mission that visited Madagascar in October/November, 1984, and a mission in June 1985, that discussed a draft of the main findings and recommendations reached. The assessment mission comprised Jochen Schmedtje (Mission Leader), Paul Dyson (Solid Fossil Fuels), Kenneth Newcombe (Cellulosic Fuels) and the following consultants: Claude Gerard (Petroleum Refining), Jean-Roger Mercier (Renewable Energies), Bernard Russell (Energy Institutions) and Katrina Sharkey (Researcher). Drawing on pertinent IDA project experience Vukota Mastilovic and Kathleen Stephenson contributed material on the power subsector and petroleum exploration, respectively.

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PREFACE

COMMENTS OF MALAGASY AUTHORITIES

This preface presents the observations and comments of the Malagasy authorities following submission of this report to the Government in June 1986.

1. Introduction

There has been discontinued progress in the energy sector since the first energy assessment mission of October 1984:

- In some projects, there was considerable progress as regards studies and in some cases even implementation;

- Steps have been taken to put into effect the measures recommended in the present report: in some cases implementation is fully under way, while in others execution is now complete. The problems which had led the UNDP/World Bank mission to make these recommendations are now no longer present;

- Options were selected for certain subsector components;

- An ESMAP mission for the electricity subsector identified priority operations in February 1986, and recommendations were included in IDA financing proposals within the framework of the energy project;

- The energy project, which covers a number of subsectors in line with the present report's recommendations, was studied by an appraisal mission in June 1986, i.e. at the time that this report was being drafted; and

- Some donors are already financing projects that seem of little importance in this report.

In sum, there are many points that need to be updated in order to get an accurate picture of the present situation.

2. Contents of Report

A. Analysis of Energy Resources

The underestimating of the economic potential of new and renewable energy resources such as wind and solar energy, biomass other than forests, wood and bagasse, in view of their insignificant share of total consumption, may discourage any further effort on the part of donors who are currently becoming involved in the development of this type of resource in Madagascar.

In addition, due to the regional imbalance in the availability of energy resources in the country, only wind or solar energy or biogas is available in some regions because of a lack of suitable sites for hydroelectric projects or those to produce energy from forest resources due to climatic conditions, as for instance in the south, the southwest and the coastal area. In addition, given currently available solar and wind energy installations in these regions, and their performance, the feasibility of using such techniques is no longer in doubt. It should also be noted that, especially in the south, the development of such resources is vital since it is tied in with the water problem.

List of other projects under way:

- aerogenerators at Antsirenana and Taolanaro, involving EDF-Indian Ocean Commission;

- rehabilitation of windmills in the south for water pumping, and search for new locations, involving GTZ (German technical assistance).

B. Options to Reduce the Firewood Crisis

The charring of sickly pine trees from upper Mangoro, viewed as a top priority among the steps to be taken, has already been the subject of a feasibility study to be financed jointly by UNDP, FAO, USAID and the World Bank. This study was discussed with the Malagasy authorities in mid-October 1986. If found to be financially and economically feasible, the project would be implemented out of energy project cofinancing or other funds. Otherwise, it would be limited to expanding traditional forest operations, or even simply abandoned. It should be noted that this project now involves shrub wood from Fanalamanga and no longer the sickly trees initially targeted. Consumer (household) tests have proved successful, and only the CIMA marketing problem remains. In addition, coalmen are now being trained under the aegis of UNDP/FAO.

Improved carbonization is also of concern to GTZ and is among the projects it intends to finance.

A study of rice husks was also prepared by World Bank experts in June 1986, but its results were quite inconclusive.

Improved stoves were discussed by the energy project appraisal mission and EDF, and it was agreed that the first step would be for EDF to initiate a distribution feasibility study, following which the World Bank would then participate in two or three regions of the country.

EDF, under Indian Ocean Islands Regional Assistance, is currently financing a project for a gas-producing plant and for gas-burning vans using coca waste from Sambava. Distribution will take place later.

C. New and Renewable Energy Sources

Hydroelectric and/or hydromechanical mini- and micro-generating stations seem to be the future source of energy for Madagascar in view of the abundance of suitable sites and the fact that they are better adapted to the Malagasy rural environment — with its scattered small villages and hamlets and dispersed tradesmen — than large-sized electricity systems.

The steps proposed include only studies, prospecting and improvements in the institutional framework, although more than 300 suitable sites have already been identified. It is to be hoped that at the same time as these steps were taken, operations, for example using the "hit-and-run" approach, will also begin. Some projects are already under way:

- Bezaha (100 kw), involving FAC and CCCE;
- Ampefy (80 kw), involving USAID; new projects will also be developed at five to ten locations under the aegis of USAID and other donors.

The February 1986 IDA electricity mission, with USAID support, already did some investigations and identified the Ambodiroka site, a feasibility study for which is under way with USTDP, to be cofinanced within the framework of the IDA energy project.

In view of the importance of these mini- and micro-hydro plants and the urgent need to replace diesel-fired generating stations, the most effective approach would be to develop projects as and when their feasibility has been established, and not to wait for the completion of the related general and global studies.

Solar and wind energy: projects under way can serve as pilot operations, and recommendations should now be geared toward their dissemination, especially since in some southern and coastal regions experience has proved the effectiveness of this type of energy source.

D. Solid Fossil Fuels

As regards local energy sources, in particular coal, the need to move ahead with feasibility studies must be stressed to ensure that full use is made of them, and in this way to eliminate imports to meet the needs of local cement works and other users.

E. Electricity

This subsector as a whole was studied by the ESMAP mission in February 1986 and recommendations were formulated. In particular, the diesel-fired stations in need of rehabilitation were examined and the cost of the works already estimated.

Most of the steps proposed in the present report were in fact included for financing under the IDA energy project, and preliminary studies are to be financed by the PPF of this project.

As regards JIRAMA's financial problems, a financial reorganization program has already been proposed by the energy project appraisal mission, and is now under way. In addition, a management audit was made in 1985.

Other reorganization measures were also taken or are in the process of being implemented.

F. Refinery Rehabilitation

An additional set of studies was prepared by BEICIP in March 1986. The first five steps recommended have been reviewed and forwarded to CCCE, which has given its agreement in principle to finance the rehabilitation work, but has requested a cofinancer.

The energy project mission and the World Bank resident representative in Madagascar have both said that the Bank will not participate in this financing but will remain benevolently neutral in this matter.

CCCE cofinancers have also been contacted and are currently studying the project brief.

Within the framework of the energy project, IDA also intends to finance a study covering an overall review of the subsector in order to find ways of reducing the cost to the country of its oil and fuel products; improve Solima's operations, marketing and distribution system; prepare an appropriate sectoral investment plan; and improve the organization of this sector and, in particular, its pricing policies.

G. Energy Pricing

Electricity

Studies to simplify tariffs and more closely reflect marginal costs are being carried out. One of the steps proposed by the energy project to increase JIRAMA's revenues is to make these new tariffs effective before January 1989: they are currently being put into effect, but only gradually.

The energy project would finance the implementation of measures aimed at increasing the use of energy surpluses, as well as power at Andekalela, in order to improve JIRAMA's financial performance. These measures would include the replacement of furnaces fired by fuel oil with electrical ones, improvement in the distribution and transmission system to allow more users to be served; and a study for the development of a low-income connections system.

H. Institutional Problems

The Government decided in February 1986 to make MIEM the focal point for energy planning and sectoral coordination. One of the components of the energy project is the study and setting up of the required structure.

Financing of the technical advisor proposed in the present report may be included under the energy project, to be covered by the Energy and Water Directorate.

The institutional problems of JIRAMA are also included under the Energy Project.

A rural energy coordination and planning committee has already been set up. Among other members, it also includes representatives of the Directorate General of Planning and the Ministry of Finance and the Economy. All that remains to make it official is for the appropriate regulations to be enacted. This committee is a more restricted version of the coordinating committee of the UNDP/World Bank Energy Assessment team.

Consultants for the JIRAMA management audit study are no longer required since the work has already been completed.

I. Manpower and Training

The Malagasy Government took steps in 1986 to reopen the agency responsible for the training of technical assistants in agriculture, stockraising and forestry.

There is a shortage of technicians, both at the middle and higher levels, that urgently needs to be remedied. It is therefore essential -- and in fact urgently necessary -- for both manpower and in particular training purposes that a unit be set up to study, plan and implement government policy in these two areas for the energy sector. The sector's development will in fact depend on the competence of its personnel.

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MAIN FINDINGS AND RECOMMENDATIONS

Main Problems

1. As one of the least developed countries in the world, Madagascar has a low consumption of energy, about 215 kgoe per capita a year. Its main energy problems are: (a) a growing fuelwood crisis, resulting from over-exploitation of the forest resources which provide about 80% of the gross energy supply, mainly for cooking; and (b) the total dependence on imports, all in the form of oil except for a small quantity of coal, with the resultant growing burden on the balance of payments. The main institutional problems are inadequate coordination and planning in the energy sector as a whole, and the lack of an effective system planning capability in the electric power subsector.

Energy Resources

2. Madagascar has significant potential energy sources. The known non-renewable sources comprise solid fossil fuels (coal, lignite and peat), heavy oil and tar sands. Prospects for petroleum are regarded as promising. Geological conditions are also considered favorable for uranium. The main renewable sources are hydropower, fuelwood and other biomass. The solar and wind energy potential is also good.

3. The hydropower potential is large and according to the most recent estimates, there are over 300 known sites with a combined potential average power output of about 7000 MW and energy production of 60,000 GWh a year. The sites cover all size ranges, with over 200 below 1 MW, about 70 in the 1-5 MW range, and 30 or so over 50 MW. The present installed capacity of 115 MW represents only a tiny fraction of the potential though the economic viability of exploiting substantially more than the present capacity has yet to be determined.

4. Coal, lignite and peat resources are considerable but they have not been exploited commercially because of the remoteness and the lack of industrial demand. The main coal deposits are in five coal fields in the Sakoa basin in south-west Madagascar, with estimated total resources of up to 1,000 million tonnes. The most important is the Sakoa field, with estimated mineable reserves of moderate ash, medium volatile steam coal of 173 million tonnes, of which 82 million tonnes would be recoverable by underground methods. According to other estimates, 23 million tonnes would be recoverable by open-pit methods.

5. The principal lignite resources occur in the Antsirabe region of the central highlands. The only deposit of potential interest is at Antanifotsy, with estimated reserves of 54 million tonnes, including 11 million tonnes of proven reserves, with a calorific value of 1900-3000 kcal/kg. There are no reserves that could be recovered by open-pit

methods, and the characteristics of the underground seam preclude economic development in the foreseeable future.

6. Widespread occurrence of peat resources have been reported although only small quantities are used as fuel for brick kilns in the Antananarivo area.

7. Madagascar's most promising oil area is the Morondava sedimentary basin in the west, where four major oil companies are now engaged in active exploration. Oil in the tar is estimated at 5-20 billion barrels but is uneconomic for development at present. The heavy oil deposits are being investigated to determine whether they could interest private exploration companies.

8. The prospects for uranium appear reasonably good, and exploration has been intensified since the late 1970s. No commercially exploitable resources have been identified, but there are numerous geological environments where they could be found, and exploration is continuing.

9. The contiguous natural forest cover is estimated at about 12.8 million hectares. Assuming that only 20% of the natural forest should be exploited for fuelwood on a sustainable basis, and counting the sustained yields of mangroves, eucalyptus and pine plantations, the gross sustainable yield of woodfuel is approximately 2.0 million toe per year, compared with a gross national demand in 1983 of 1.7 million toe. However, the forest cover is very unevenly distributed, and the mission estimates that the overall nationwide surplus of about 300,000 toe translates into an effective deficit of about 600,000 toe annually, which is the shortage in the central highlands provinces of Antananarivo (419,000 toe) and Fianarantsoa (181,000 toe), since wood cannot at present be economically transported from surplus to deficit provinces. Hence, in deficit areas forest stocks are being heavily depleted.

10. There are many crop residues which could be used as fuel. The most important with commercial potential is rice husk, with an estimated annual production of about 500,000 tonnes (as received), though only about 16,000 tonnes per year could be briquetted to provide fuel for households and industry during the 1980s. Sugar crop residues, with estimated maximum production of 260,000 odt (tonnes, oven dry basis), is the other main potential source for production of electricity to displace diesel generation, but again the utilization of this resource is constrained by limited demand for power and solid fuels in the sugar production zones, and currently available surpluses are only 29,000-42,000 odt/year, equivalent to 19-28 GWh/year.

11. The direct solar radiation regime is high throughout Madagascar but the mission found only a very small economic potential for the application of solar water heating and solar photovoltaic electricity generating technologies. Wind energy resources are also abundant, although unevenly distributed. Wind energy has long been utilized for

water pumping in southern Madagascar and preliminary studies suggest wind power generation might be competitive with diesel generation in remote locations, where the delivered cost of diesel oil is high. Biogas has been found to have very limited economic potential despite the large domestic cattle population. Geothermal resources have been identified with temperatures high enough for electricity generation but there is little prospect they can be economically developed during the next decade or so.

Options for Alleviating the Fuelwood Crisis

12. Over-exploitation of the forests for fuelwood, particularly in the vicinity of major population centers, is a major factor in reducing the forest cover. The annual rate of deforestation is estimated at 165,000 hectares in the period 1976-1980 and 150,000 hectares at present, and the primary cause of this deforestation is agricultural clearing. At this rate, there would be a loss of 1.5 million hectares over the next ten years, or about 12% of the total forest cover, with grave economic and social consequences. Once forest cover is greatly reduced as a result of intensified agricultural activity, the time spent gathering firewood in rural areas will increase, reducing rural labor productivity, and the price of woodfuels in urban areas will escalate rapidly as rural sources are depleted. Land erosion will also accelerate beyond its already serious proportions with multiple negative economic effects.

13. The main focus of the fuelwood problem is in Antananarivo where, over the next ten years, if no corrective action is taken, the gap between demand and supply is projected to increase to 680,000 toe a year. An effective strategy for reversing this trend must address both the supply and demand sides of the equation, seeking to augment fuelwood supplies and at the same time restrain consumption by demand management and the substitution of other household cooking fuels for wood, such as hydro-electricity, kerosene and crop residues.

14. The options for increasing fuelwood supplies range from long-term supply measures, based on plantation development and encouragement of rural tree-planting, which have little impact within a decade, to short to medium-term measures designed to produce results in the next 5-7 years by increasing the productivity of the existing plantations and the recovery from currently available woodfuel resources, such as sawmill wastes, logging wastes and overmature or degraded forests (para. 2.1-2.8).

15. The short-term supply options comprise the following measures:

(a) Improving coppice management. Under the present pattern of exploitation, there is no system of plantation management. This results in lower yields and greater susceptibility to disease. Trimming of the coppice regrowth to two or three of the strongest shoots after 3-6 months could increase by 25% the yield of fuel quality biomass (para. 2.9(a))

(b) Exploiting underutilized forest resources. The present method of forest exploitation for timber extraction results in retrievable, but currently unutilized, fuelwood quality material estimated by the mission at 100 m^3 per hectare. The 27,000 hectares under exploitation at present could conceivably yield 1.8 million tonnes of fuelwood (twe), or about one-third of present national demand. Only a small proportion of this fuel quality biomass is economically accessible at present because of poor roads and lack of transportation, and because forest concessionaires are not encouraged to recover even the accessible material as firewood or charcoal. However, the mission estimates that under optimal circumstances up to one-third of this could be recovered, mostly through carbonization, within the next six years and over one-half within the next decade. For the purposes of making long-term supply projections the mission has assumed that about 1.4 million twe, roughly 40% of the estimated resource available, will be retrieved by 1995.

(c) Recovery of sawmill and wood-processing wastes. Timber processing commonly produces large quantities of unrecovered fuel quality residues. The annual log input volume is estimated at 130,000 m^3/year, hence about 45,000 m^3 is available as offcut and slabs, which the mission believes can be carbonized to produce up to 5,600 tonnes of charcoal for urban markets with favorable economic returns (para. 2.9(c)).

(d) Improved carbonization efficiency. Charcoal is produced almost entirely by traditional above-ground earthen kilns. The average charcoal yield is probably about 15% of the dry weight of the charge, and the net returns to labor are marginally below the average daily wage of unskilled workers. Improved types of kiln promise up to 50% higher yields per unit of wood consumed and lower charcoal production costs (para. 2.9(d)).

(e) Carbonization of Haut Mangoro pine smallwood. At least 15,000 hectares of pines with stunted growth caused by nutritional deficiency could yield 12,500 tonnes of charcoal per year if harvested over five years. Thinnings from the main plantation could yield another 9,000 tonnes/year of charcoal. Lump charcoal production by decentralized small-scale kiln operations to serve household and industrial markets is both economically and strategically desirable. By contrast, the central pelletization and chip charcoal production is neither the most practical nor the most economic utilization of the valuable pine waste resource (para. 2.9(e)).

16. In addition to these measures to increase supply in the short- to medium-term, the most important long-term supply options which deserve immediate attention are:

(a) Centralized peri-urban plantations. Plantation-grown firewood could become economically the least-cost energy source for household cooking if an efficient metal wood-burning stove can replace open fires. However, prerequisites for a national fuelwood plantation investment program would be a basic inventory of forest cover and effective land-use planning.

(b) Urban reforestation. Low-lying swampy areas in the Antananarivo area could sustain high yields of fuelwood for households or brickworks, and similar areas may exist near other large towns. Appropriate incentives to plant and protect urban fuelwood lots should be investigated (para. 2.13.(b).

(c) Rural afforestation. Well-planned and executed tree-planting at the village/farm level and protection of remaining forests for sustained yield are essential not only for sustained fuelwood supply, but also for sustained agricultural production. In the short term, there is some scope for improved production and distribution of appropriate tree species. For any larger scale programs to be successful, however, forestry sector institutions need to be greatly strengthened with technical assistance for planning, management and localized skill-training.

17. Demand management through the introduction of improved charcoal and wood stoves is the main option for reducing per capita fuelwood consumption. The Madagascar charcoal cooker could, with minor changes, be made 25% more fuel-efficient, and consideration should be given to the introduction of portable metal wood stoves which consume up to 50% less fuel than open fires. The actual aggregate fuel savings will depend on the success of extensive consumer trials (para. 2.12).

18. Inter-fuel substitution, another means of reducing the demand for fuelwood, comprises short-term and long-term measures. The short-term options are: (a) briquetting of rice husks for use as household fuel in the Antananarivo area, where presently 17,000 tonnes/year of rice husks are produced (20,000 twe); and (b) greater use of kerosene both through the introduction of more efficient kerosene stoves and increased supply; and (c) greater use of surplus hydro electricity for cooking along with efficient electric rice cookers. If 10% of the 100,000 households in Antananarivo substituted kerosene, and 10% electricity for charcoal, charcoal demand would decrease by 22,500 tonnes/year, or about 200,000 twe. This reduction would require a relatively modest 4,600 tonnes of kerosene and 30 GWh of electricity p.a., i.e. less than 10% of energy generating capacity (para. 2.14).

19. One major long-term biomass fuel substitution option may be expanded use of agricultural residues, some of which may eventually become economically accessible assuming continuing real price increases for fuelwood. The most promising potential source is the rice crop of the Lac Aloatra region, which yields annually about 35,000 tonnes of rice husks and 110,000 tonnes of rice straw (para. 2.15).

Recommendations

20. In the light of the preceding review of the options for improving the fuelwood demand/supply situation, the mission makes the following recommendations for action (in order of priority under each heading):

Top Priority Actions

(a) Project Measures

(i) Carbonizing of Haut Mangoro Pine Smallwood, Thinnings, and Sawmill Waste: detailed design of an overall lump charcoal production investment program including pilot small-holder or semi-centralized based carbonization systems for the uses of each residue; development of detailed resource assessment and carbonizing schedule; credit and other incentives for entrepreneurs; institutional reorganization; and facilitating infrastructure development and detailed project design. 1/

(ii) Rural Afforestation: Programs similar to the "micro-boisement" program of the Government and those recommended by the Bank as part of the proposed Forestry III project should be implemented in order to gain early practical experience in rural afforestation. In the context of energy supply, specification of precise quantitative needs by location; and review and design of extension service facilities, infrastructure requirements, technical packages, required incentives and manpower training and development programs.

(iii) Cooking Electrification: in order to determine whether this is an attractive option, a review of detailed costs of strengthening and expanding the electricity distribution

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1/ As of early 1986, terms of reference have been finalized for a detailed feasibility study on carbonization by decentralized, small-scale kilns. Furthermore, it seems likely that the resources involved are far greater than previously thought. It is possible that up to 40,000 tonnes of charcoal could be produced annually from the thinnings.

networks to accommodate for more electric cooking, including tariff incentives, appliance provision and a brief analysis of SRMC and LRMC under a simplified system expansion scenario (in parallel with studies on power efficiency and means of economically utilizing surplus hydropower in the main interconnected power system).

(iv) Expanded Use of Kerosene for Cooking: macroeconomic and petroleum subsector review to determine fiscal and logistical constraints to expanding kerosene supplies, from the present refinery and by imports, and subject to results of these reviews, encouragement of use of improved kerosene stoves, e.g., by reducing duties on imported stoves or encouraging local production of improved kerosene stoves.

(v) Rice Husk Briquette Production: feasibility and design study, followed by early commercial-scale demonstration of rice husk briquette plant in the Antananarivo area, including monitoring and evaluation of performance, consumer acceptance trials of raw and carbonized briquettes, and development of large scale investment program for rice industry.

(b) Technical Assistance and Incentive Schemes:

(i) Charcoal-Maker Training and Incentive Schemes: provision of expertise for demonstrating simple measures for upgrading traditional earthen kilns through training and extension programs ultimately reaching 2,000 charcoal-makers a year, demonstrating and transferring new techniques and providing credit or grant assistance to motivate required change.

(ii) Forest and Tree Resource Inventory: to lay the groundwork for planning long-term programs of afforestation in the vicinity of each major demand center, DEF should extend its proposed inventory of the forest and tree cover, and potential forest land, in the hinterland of six major urban centers to all significant fuelwood demand centers, and should ensure that the inventory provides total standing biomass by class. As a first step, a brief inventory design study should be made to review existing maps and data, and based on the present mapping program, to cost the required inventory program, including staff training and equipment.

(iii) Forestry Institution Building: review of the organization, management, training needs and equipment needs of the forestry departments of DEF (para. 2.26).

(iv) Sawmill Waste Recovery: an inventory should be made of sawmills and their waste production within reasonable transport access of major urban markets, and a fully commercial program of recovery devised starting with the carbonization of slab wastes and leading to initially small-scale sawdust and shavings briquetting.

High Priority Actions

(a) Coppice Management: mounting trials and designing extension programs aimed at increasing productivity of existing eucalyptus plantations through improved coppice harvesting and coppice management techniques.

(b) Demand Analyses and Cooking Efficiency Programs: undertake detailed household energy surveys to specify the level and pattern of fuel cooking practices, together with household trials of improved fuelwood, charcoal, kerosene and electric stoves to test consumer acceptance in each socio-cultural setting.

(c) Fuelwood Plantation Program Design: establish the economic and financial viability of peri-urban fuelwood plantations and where justified, specify precise quantitative needs and relative economic merits of fuelwood plantations vis-a-vis other household cooking fuel options by major demand center, and review and design institutional arrangements, interfaces with the private sector, technical options, financing options and overall implementation schedules and investment programs.

(d) With the object of exploiting underutilized forest resources, an early evaluation should be made of the most common logging practices in the lumber industry and the forest types concerned so as to specify:

(i) the actual residues and cull volumes by class for each major forest type for forests in the hinterland of the major urban markets;

(ii) the financial and marginal economic cost of retrieving as charcoal or firewood each class of fuelwood identified;

(iii) a profile of the logistics for future logging and woodfuels recovery operations for each of the forests concerned as well as the additional capital outlay required to broaden the scope of logging to include charcoal production;

(iv) the institutional arrangements within Government and between Government and the private sector which appear optimal to facilitate the maximum economic level of woodfuel and timber production from State forests;

(v) the overall economic costs and benefits of improved forest management including the expected higher yield and shorter rotation for commercial timber species; and

(vi) an investment and implementation schedule for the required policies, commercial arrangements, infrastructure development and retrieval of the timber and woodfuels concerned for each major demand center.

Lower Priority Actions

(a) A review should be made of the prospects for workable arrangements, including appropriate incentives for local residents or leasers to reforest and protect for sustained fuelwood production the swamp land in the urban area of Antananarivo and other similarly productive urban areas. This will require an inventory of suitable inter-urban and peri-urban land for strip planting, roadside planting or the establishment of small woodlots.

(b) Energy Supply to Agro-Industrial Complexes: initiate an integrated planning study for stabilizing and reducing the cost of supplying energy to the Lac Aloatra region, the main "rice bowl" of the nation, where the impact of deforestation is particularly severe and the cost of mechanical and electrical power is high (see Annex 11 for draft Terms of Reference).

21. The mission's analysis of the potential impact of the measures recommended above shows that under the most favorable circumstances the deficit in Antananarivo province can be reduced by about 750,000 twe by 1995 (i.e. from 2.17 million twe without the proposed measures to 1.41 million twe with them, Annex 3). The mission has not made similar analyses for other provinces because of data uncertainties, but the overall supply/demand situation should be reviewed again following completion of the recommended resource inventories and demand surveys.

Other Renewable Energy Options

22. The mission concluded the following with respect to other renewable energy sources:

(a) the use of briquetted rice residues as household fuel (para. 2.36) need not preclude the use of some of the unprocessed residues for electricity generation, given the large size of the resource. A preliminary analysis suggests that Lac Aloatra rice husks could generate up to 22 GWh/year of electricity at about half the fuel cost of diesel generation;

(b) With relatively straightforward sugar mill modifications, bagasse surplus could be produced which could generate up to 24 GWh in substitution for local diesel power generation, saving up to 6000 toe/year of diesel oil. In particular, the study of the sugar industry being financed by French aid should be followed up if necessary, by further pre-investment work on the potential for bagasse-fueled electricity supply (para. 2.37);

(c) Regarding the production of ethanol from molasses as a gasoline substitute, the mission's analysis of the Ambilobe ethanol project indicates that the variable costs of production alone would exceed the landed cost of gasoline. Thus ethanol from Ambilobe does not present an attractive option as a substitute fuel for gasoline. A recent study, however, suggests that there are sufficient higher value, industrial uses for ethanol to make its production for that market attractive from an economic standpoint (para. 2.36);

(d) A sample analysis by the mission suggests that some of the possible small-scale hydropower schemes, for which there are over 200 identified sites, may be competitive with diesel generation in suitable circumstances, hence a review should be made of the small-scale hydropower potential to identify any sites which could economically displace diesel generation (para. 2.40, 2.45).

Recommendations

Top Priority Actions

(a) A review should be made of all previous assessments of the small-scale hydropower potential in order to determine which, if any, of the identified sites can economically displace existing diesel power generation, public or private; and

(b) If this study demonstrates a significant economic potential for small-scale hydropower development, it should be followed immediately by a second pre-feasibility phase to:

(i) define the institutional, legal and financial framework for development in both the public and private sectors;

(ii) formulate an investment program for the public sector, based on design and costing studies for several mini-hydro projects of demonstrated economic viability; and

(iii) estimate the finance required to encourage private sector participation in development; and

(c) A central agency should be established for hydrological data collection and interpretation.

High Priority Actions

(a) The CCCE study of the sugar industry should be monitored and followed up, if necessary, by further pre-investment work on the potential for bagasse-fueled electricity supply. Where a power market does not exist, or is too small to absorb the bagasse surplus, production of briquetted fuel for industry and households should be evaluated.

Lower Priority Actions

(a) The Government should encourage private sector application of photovoltaic power systems by allowing their importation without duty or taxes wherever diesel-fueled electricity generation would be the source of electric water heating (e.g. in large settlements for enclave industries, such as Fanamalanga and SOMALAC); and

(b) Wind energy research should concentrate on site specific design, regulation, minimum maintenance programs and service training. One or two pilot projects up to, say, 100 kW, could logically follow, after economic and market analysis, in close coordination with JIRAMA, although operated as enclave projects under separate management.

Development of Solid Fossil Fuels

23. There are no plans for lignite or peat development (para. 3.14). With respect to the coal deposits in the Sakoa basin (paras 3.15-3.18), although Madagascar has extensive resources of bituminous coal potentially suitable for the international thermal coal market, there is little possibility of such development in the foreseeable future. Market conditions are poor for potential new producers, with stagnant prices and little prospect of significant real price increases over the next 10 years. Besides large infrastructure investments, the probability of locating reserves recoverable at competitive prices is low, since all present indications are that the bulk of the resources would have to be developed by relatively high cost underground mining methods.

24. The critical issue concerning the proposed small coal mine is its size. BP has proposed a study for a mine producing 50,000-100,000 tonnes per year, which the Malagasy authorities have expressed an interest in. This would appear to be appropriate, since the projected internal market is expected to depend essentially on the demand of the cement industry, which the mission estimates not to exceed 33,000 tonnes

in 1990, or 50,000 tonnes in 2000. The maximum demand other than for cement is unlikely to exceed 10,000 tonnes/year by 1995, in view of the small industrial sector and the lack of infrastructure to handle and deliver coal at competitive prices. This suggests a maximum internal market of 60,000 tonnes by 2000. The potential market for indigenous coal will be only 40,000 tonnes, because of its unsuitability for cement kilns now under construction. Furthermore, an ongoing supply of about 10,000 tonnes per year of lump charcoal from Haut Mangoro pines clearing and thinning may be best used in cement production displacing imported coal. Consideration has been given to carrying out a feasibility study of a mine producing 400,000 tonnes per year which presupposes that the excess over domestic demand could be exported. This is unlikely since the costs f.o.b. Toliara of US$30-40 (1984 US$) per tonne would well exceed current and projected costs of coal from South Africa or Australia. Coal from such a mine would also be uncompetitive with imported coal for internal consumption.

Recommendations

(a) First, an evaluation of peat resources should be undertaken in view of the rapidly rising prices of fuelwood and the reported widespread peat occurrences;

(b) Second, the Government should encourage further exploration of the coal resources if this can be done at no cost to the Government under a suitable agreement with BP; and

(c) Third, no further investigation of lignite resources should be undertaken at present.

Electric Power Subsector Development

25. JIRAMA's projection of electricity demand implies a reversal of the recent trend, with a growth rate of around 5% p.a. to 1995 compared with 2.9% p.a. in 1979-1983. This high rate is due to the high projections for the main interconnected power system, where sales are projected to grow at over 7% p.a. on average to 1990, despite the assumption that there will be no major new industrial loads (para. 4.2-4.4). In the mission's view this load forecast is too high and it recommends a critical and detailed review of the interconnected system load projections to 1990.

26. It is unlikely that any major new electricity-consuming project, such as ferrochrome production, will be economically justified before the turn of this century; however, if this eventuated, it would cause a much greater increase in demand than now forecast and would need to be properly phased, therefore, with any additional power facilities required to ensure that power supply continued to be adequate. The proposed cement plant at Amboanio in the Mahajanga region, for example,

would add another 50 GWh to the projected 1990 consumption in the region of some 72 GWh.

27. On the supply side, the main issue in the power subsector is the large power surplus in the interconnected system, estimated at almost 150 GWh in 1990, resulting from the commissioning of the Andekaleka hydropower plant in 1982 and the slow growth of electricity demand in recent years. Even under JIRAMA's demand projections, this surplus is unlikely to be utilized until near the end of the century (para. 4.7-4.12). However, JIRAMA has to service the debt of the Andekaleka scheme throughout this period and low utilization of this investment has serious repercussions for financial performance if action on tariff levels and other financial measures is not taken accordingly, and if new economic uses, hence sales, of electricity are not found soon.

28. Parts of the transmission system need strengthening to improve the supply. The underdeveloped condition of parts of the distribution network, and inadequate house wiring systems, are an obstacle to the development of household consumption through wider use of appliances, such as electric rice cookers. In addition, JIRAMA is not able to keep up with the demand for connections because of a lack of materials.

Recommendations

(a) With regard to demand issues:

(i) given the need for close monitoring of the development of demand, particularly in the industrial sector, JIRAMA's load research and forecasting capability should be strengthened, with the emphasis on regular updating of short- and medium-term projections. The proposed technical assistance for training should include some provision for this (para. 55(d)(i).

(ii) JIRAMA should investigate the possibility of promoting household consumption of electricity, e.g. for cooking, in view of the hydropower surplus and the desirability of restraining the growth of fuelwood consumption. This will entail analyzing: (i) the effect of increased consumption on peak demand; (ii) the cost of strengthening distribution networks and improving household wiring; (iii) the possibilities of promoting the development of a low-cost, high-efficiency electric rice cooker; and (iv) the innovative tariff structures required.

(iii) It is particularly important for JIRAMA to determine the impact on the system energy and capacity balance of the recently revised estimate of the ferrochrome industry load in order to determine the likely timing and scale of new capacity and energy additions, should this industry proceed, and to estimate the true cost of supply to the industry, and hence appropriate tariff levels on a daily and seasonal basis.

(b) With regard to supply issues:

(i) JIRAMA, with the assistance of consultants, should examine the scope for accelerated utilization of the hydropower surplus within the interconnected system through further substitution of diesel generation (in addition to Toamasina) and further industrial use of electricity wherever this is economic.

(ii) Recent analysis indicates that, in respect of supply to Antsirabe, an economic justification exists to construct a new 138-kV line as well as for strengthening the existing 63-kV transmission line; however, there may be serious funding difficulties for the major 138-kV line investment.

(iii) The mission strongly supports proposals to finance rehabilitation and reinforcement of distribution to eliminate bottlenecks and reduce overloading of main feeders.

(iv) The Government should monitor and follow-up if necessary the French-financed study of sugar industry development with particular reference to displacing local diesel generation with bagasse-fueled electricity supply.

(v) In sequence with the above-mentioned supply and demand analyses, JIRAMA should undertake a detailed least cost expansion plan to meet the most likely scenario of projected capacity and energy demand on the interconnected system with and without the proposed ferrochrome demand.

(vi) Diesel generation plants in the major supply centers should be audited and, if necessary, rehabilitated. The mission concludes that, for the time being, continued operation of existing thermal generation in these centers is probably the least cost supply option.

(vii) The recommendations for transmission, distribution and generation rehabilitation made above can be dealt with in an integrated way by undertaking one overall "Power Sector Efficiency Audit" encompassing all power system efficiency improvements. 2/

2/ Field work for such a study was undertaken in March 1986, with joint UNDP/World Bank technical assistance. The results of this analysis will be available towards mid-1986.

Refinery Rehabilitation

29. The sole petroleum refinery, which dates from 1966 and has been operated by the government-owned company, SOLIMA, since 1976, was shut down in September 1983 following a fire in the topping furnace, and resumed limited operation in September 1984. A June 1984 study by BEICIP supported the findings of earlier analyses that rehabilitation of the refinery to give it a useful working life of another fifteen years was technically feasible and also economically justifiable. The French "Caisse Centrale de Cooperation Economique" (CCCE) subsequently opened a line of credit of FF 43 million (US$4.8 million) for a detailed feasibility study on the rehabilitation project, finance of the most urgent rehabilitation measures, and training of operating staff.

30. The results of the feasibility study, again by BEICIP, were available in October 1985. In addition to the rehabilitation, BEICIP proposes some minor modifications to improve the refinery's performance. These include increasing the yield of middle distillates and reducing losses. The total cost of the rehabilitation and the improvements is estimated at 1985 FF140 million (approximately US$20 million). 3/

31. To evaluate the rehabilitation project, BEICIP compared it wih the alternative, which would be to shut down the refinery and import finished petroleum products for the domestic market. The main factors taken into account in evaluating the project are: (a) the projected demand for petroleum products in Madagascar; (b) the expected international prices for crude oil and products, and their respective import costs, (c) refinery margins (i.e. the difference between the value of the refined products and the crude oil cost); (d) the scope for technical improvements to the refinery; (e) product exports; and (f) the capital costs of the rehabilitation project and the operating costs of the refinery.

32. BEICIP postulated a high and a low scenario for projected petroleum product demand in Madagascar. In view of Madagascar's current economic situation, the low demand scenario seems more probable. It entails a growth in total demand of somewhat over 1% a year until 1990, and over 2% a year in the 1990s. With respect to prices, BEICIP chose two sets of crude oil and product prices on which to base its analysis, the average prices (c.i.f. Toamasina) paid by SOLIMA in 1984 and in the first semester of 1985. These prices are significantly higher than those prevailing at the time on the international competitive market. This is

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3/ A cyclone struck the refinery in March 1986, causing about US$1.0 million worth of damage. The required repairs are covered by SOLIMA's insurance policy, however, and the rehabilitation project as defined by BEICIP has not been affected.

because, due to its restrictive credit terms (reflecting the foreign exchange shortage), SOLIMA must pay a surcharge for crude oil and for products. For purposes of project analysis, BEICIP assumed that SOLIMA would keep paying this surcharge for the first three years of the project, but that it would then gradually be reduced to zero by the fifth year.

33. The results of BEICIP's economic analysis show that, based on the treatment of Arab light crude to meet the low demand scenario, the projects's attractive 26% of return under 1984 price conditions decreases significantly to a marginal 10% on the basis of prices from the first half of 1985. This and further analyses carried out by BEICIP underscore the sensitivity of the project's viability to changes in the relative prices of crude oil and petroleum products. It is likely that, following the early 1986 sharp decline in world oil prices and the growing adoption of the concept of "refinery netback" pricing for crude oil, the refinery margin will increase in relative terms for efficiently run refineries. The rate of return for the rehabilitation project, which depends on the refinery margin, would therefore also increase under these conditions.

34. As noted above, the BEICIP proposal does include measures to increase the yield of middle distillates. It is possible, however, to produce an even higher proportion of distillates by upgrading surplus residual fuel oil. This modernization would entail reorganizing and remodelling the visbreaking complex built in 1982. It would significantly improve the refinery's operating flexibility and profitability, for example by allowing SOLIMA to satisfy the domestic demand by processing less crude. The additional investment required is estimated at around US$8.0 million, with a payout period of about 2.5 years. The existing petroleum supply-distribution system should also be rehabilitated and modernized, at a further cost estimated to be about US$4.0 million.

Recommendations

(a) The technical feasibility of the modernization proposal, and especially its effect on the overall viability of the rehabilitation project as defined by BEICIP, should be studied in greater detail. The analysis should be carried out with the low demand scenario as the base case. Particular attention should be paid to: the match between refinery output and domestic demand: the potential market for SOLIMA exports; the suitable crude for the refinery in light of SOLIMA's supply constraints; the implications for least cost petroleum product supply of enabling SOLIMA to operate freely in the international petroleum market, and appropriate foreign exchange/procurement arrangements; minimizing refinery losses through energy conservation measures; and especially, given the current uncertainty in the oil market, the project's viability under existing petroleum prices and the sensitivity of its rate of return to changes in them. The rehabilitation and modernization of the petroleum supply-distribution system should also be examined in detail under this study.

(b) SOLIMA should improve its procedures in the fields of refinery planning and operation process analysis. This will require technical assistance for special training of staff to (i) develop process data on each unit; (ii) obtain good data on yields and quality of all possible crudes for the refinery; and (iii) write a computer program to help in the selection of type and quantity of crude to be processed and of products for export or import. This will require technical assistance (para. 5.29) at an estimated cost of FF 10 million (US$1.4 million), which is included in the cost of the rehabilitation project.

Energy Pricing

35. Domestic prices for petroleum products fully reflect their economic cost and for the most part well exceed the latter. The May 1984 increase in these prices eliminated the previously existing - and only remaining - subsidy to kerosene.

36. A remaining major issue is the relative prices of gas oil and kerosene to gasoline, which are only 49% and 42%, respectively, of the gasoline price. This pricing structure has given the wrong signal to consumers regarding the economic cost of gas oil consumption and is likely to have resulted in additional imports of gas oil and heavy vehicles with consequent higher road maintenance cost, and in blending of kerosene with gas oil for use in diesel engines.

37. For historical reasons, electricity tariffs are extraordinarily complex and difficult to administer as different tariffs obtain for different districts of the interconnected system and for each of the many regional power systems as well. For the most part, these tariff levels relate only coincidentally to actual cost of supply, and tariff considerations are primarily financial rather than economic. JIRAMA is well aware of the irrationality of the present tariff structure largely inherited from the time when each local government council administered its own power supply, and has endeavoured, so far without success, to implement significant tariff reforms so as to reflect the economic cost of power supply and achieve tariff simplification. The need for tariff reform is urgent not only for the above-mentioned reasons but because the huge hydropower surplus which may prevail through the mid-1990s, or beyond, offers some prospect of relief from mounting woodfuel prices as well as for reducing the oil import bill. Moreover, JIRAMA needs to develop a tariff structure which will encourage new uses of electricity, greatly increasing its revenues and its ability to service its substantial debt burden.

38. Firewood and charcoal prices are left to be determined in the market place, their regulation by government being impractical. They have risen substantially in recent years and are bound to increase further, especially in Antananarivo where from 1973 to 1984 they rose on the order of 50% and 30%, respectively, in real terms (Annex 6.3). Even so, current market prices for woodfuels are still about one-quarter to one-half below their economic costs if the full replacement costs based on new fuelwood plantations are considered (Table 2.4). The pace and extent of further woodfuel price increases will largely depend on the implementation or otherwise of appropriate measures to improve woodfuel supply and demand management (paras. 2.45-2.48).

Recommendations

(a) Top Priority Action. A thorough tariff review should be carried out in parallel with a detailed review of demand forecasts for each of the major supply centers and the proposed least cost system expansion studies (para. 4.25). Furthermore, this review should propose a simplified tariff structure based on the marginal economic cost of supply, while ensuring that JIRAMA is self-supporting financially. In view of the anticipated excess hydro capacity over the next decade or so and JIRAMA's substantial debt service burden, it is recommended that the study should examine ways of increasing capacity and energy utilization, and hence revenue through appropriate pricing to industrial and residential consumers.

(b) High Priority Action. A study should be undertaken of the scope and quantitative importance of inefficient inter-transport fuel substitution in Madagascar and of the effects of a narrowing of the gasoline-gasoil-kerosene price differentials on the balance of payments, public finance and income distribution.

Institutional Issues

Sectoral Issues

39. The main general institutional issues in the energy sector are: (a) the inadequate coordination of the activities of the numerous ministries and agencies in the sector; and (b) the weaknesses in energy planning. Under its decree the Ministry of Industry, Energy and Mines (MIEM) is expected to exercise the coordinating function in the sector, but it has not been able so far to effectively take on this role. This is partly because of its own relatively recent creation (July 1983) and understaffing in relation to its responsibilities, and partly because the National Military Office for Strategic Industries (OMNIS) reports directly to the President of the Republic without a defined link to MIEM. OMNIS has important responsibilities in relation to oil, coal and

uranium development and has been involved in energy planning prior to MIEM's creation. The lack of clarity in roles and relationships results in serious weaknesses in sector-wide investment programming (para. 7.1).

40. Lack of long-term manpower planning for the energy sector is evident. This is compounded by severe restrictions in recent years on recurrent expenditures which have greatly reduced provision for training in the energy sector. Some agencies in the sector have been making little, if any, provision for training, resulting in a steady erosion of formal training programs and extension services. A related problem is that professional technical staff in the energy sector tend to be seriously out of date regarding the latest developments in their professional specialities, because of cutbacks in the acquisition of technical journals and books and in provision for refresher courses, attendance at seminars, symposia and the like (para. 7.2, 7.11-7.13). This problem needs to be addressed by suitable technical assistance in connection with specific projects.

Energy Forestry Subsector

41. The main institutional problems confronting energy forestry are:

(a) lack of effective planning capability, in relation both to strategic planning for forest management and development and to the fuelwood and charcoal markets which constitute the main outlets for forest products;

(b) lack of an adequate data base for planning, as evidenced in the absence of standing biomass resource inventories and hard woodfuel and timber consumption data by region. This problem is compounded by shortages of modern office equipment, which cause serious delays in data processing and analyses;

(c) weakness in business management expertise to define means of supporting private sector energy forestry enterprises. Technical deficiencies are partly due to the loss of experienced key staff to the parastatal organization, Fanalamanga, to the CENRADERU (National Center for Applied Research in Rural Development) and elsewhere;

(d) shortage of qualified professional high-level foresters partly reflecting relative lack of interest in forestry as a profession in recent years. There also is a shortage of technicians due to the fact that eight "lycees agricoles", which used to train these technicians, have not been functioning for over 10 years. As a result, DEF has not been able to replace technicians leaving its service on retirement or for other reasons; and

(e) MPAEF's training programs give low priority to forestry training, the main emphasis being on training in organization, management and planning. This underlines the importance of making specific provision for training needs in forestry projects.

Coal Subsector

42. The main institutional issue in the coal subsector concerns the respective responsibilities of MIEM and OMNIS for studies related to the development of coal resources. According to its terms of reference, this is the responsibility of the Mining Projects Division of the Mines and Geology Service of MIEM. Since 1983, however, when OMNIS negotiated a contract with BP for a coal study, OMNIS has effectively taken over this responsibility, although the decree establishing OMNIS says nothing about coal. This arrangement has evidently been mutually agreed between MIEM and OMNIS, partly because of the experience OMNIS already has in negotiating petroleum exploration and development agreements.

Electric Power Subsector

43. The main institutional issues in the electric power subsector are:

(a) the lack of an effective system planning capability for making realistic demand projections and formulating development programs to satisfy the demand at least-cost to the economy. Electricite de France (EDF) completed a system planning study two years ago, but no action appears to have been taken on its findings or on updating in light of recent demand trends;

(b) lack of any clearly identified institutional responsibility for maintaining an up-to-date inventory of potential large and small hydropower sites, which can be ranked in economic merit order for future system development purposes;

(c) financial planning and management information systems generally appear to be weak in JIRAMA, partly because of a national shortage of competent financial management staff and also because of shortages of essential office equipment and supplies.

Petroleum Subsector

44. The main issues are:

(a) delays in the processing of management information in SOLIMA, affecting the flow of essential information not only within SOLIMA but from SOLIMA to MIEM. This is partly due to equipment shortages, especially of minicomputers; and

(b) refinery operating and maintenance staff have been unable to keep up-to-date with modern refinery technique and practice because of the lack of foreign exchange for training. The problem should be alleviated by the provision for training under the recent French credit for refinery rehabilitation.

Recommendations

45. The mission's recommendations for dealing with the institutional issues identified above are as follows:

(a) Sectoral

(i) The Government should urgently consider and reach an early decision on the establishment and implementation of appropriate institutional arrangements to ensure effective energy sector coordination at the national level, with particular emphasis on integrated energy investment planning according to the principles of minimizing the relevant economic cost. To this end, an energy adviser to the Government, should be appointed for two years at a cost of US$150,000 to help in setting up such arrangements and making them work. He would also advise on any changes necessary in relation to investment planning and staff training.

(ii) Technical assistance should also be provided for essential office equipment, especially minicomputers for MIEM, at an estimated cost of US$250,000.

(iii) Short-term consultancies should be arranged, e.g. for training in specific areas, as identified by the energy adviser. The estimated cost is US$100,000.

(b) Energy Forestry Subsector

(i) Organization, management, training programs and equipment needs of the forestry departments of DEF should be carried out.

(c) Coal Subsector

(i) The respective responsibilities of MIEM and OMNIS for coal exploration and development studies should be clearly defined to ensure future coordination.

(d) Electric Power Subsector

(i) JIRAMA should adopt an urgent action program to strengthen system planning along the lines recommended in the EDF planning study of 1982. 4/ To support these efforts, technical assistance should be provided for the training of at least three JIRAMA engineers in the areas of load forecasting, generation and transmission planning, and power system analyses.

(ii) JIRAMA should appoint a consultant to review all available information on potential major hydropower sites and prepare a preliminary ranking in economic merit order. The consultant should recommend desirable changes in JIRAMA's internal organization to ensure regular review and updating of the inventory of hydropower sites.

(iii) A committee should be set up under the chairmanship of the Director of Energy of MIEM for the coordination of rural energy planning. This should include representatives of JIRAMA, the Rural Infrastructure Directorate of MPARA, the Directorate of Fisheries and Forests of MPAEF, the Directorate of Technological Research of MRSTD, IMI, the HERY VAO company and DUEN.

(iv) The mission supports JIRAMA's engaging the services of consultants to carry out a diagnosis of its financial management and make recommendations for improvement.

(e) Petroleum Subsector

(i) SOLIMA's management information system should be reviewed. This should be accompanied by an urgent review of its office equipment needs, especially for data processing and computing. This could be a task for the proposed energy adviser.

Energy Sector Investment Requirements

46. Based on the investment proposals and recommendations presented in this report, the mission has drawn up a priority ranked energy sector investment program for 1986-1990. This is the mission's view of priorities, based strictly on economic criteria. The proposed 5-year program totals US$138 million equivalent (Table 7.1), including nearly US$10 million for technical assistance and studies (Table 7.2), the financing of which remains to be considered in the content of overall

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4/ As of 1986, a Directorate of Economic Studies and Planning had been created within JIRAMA. Thus, all planning functions have been regrouped, along the lines recommended by EDF.

public sector investment programming. Top priority investments amount to US$46 million of this total, high priority ones to US$41 million and those of lower priority to US$31 million; the refinery rehabilitation project (US$20.0 million) has not been ranked, pending a detailed analysis of the effect of the proposed refinery modernization on the viability of the rehabilitation project (para. 5.19). The top and high priority investments aim mainly at improving the increasingly precarious supply of household fuels, particularly in the Antananarivo region, while at the same time utilizing some of the large excess hydroelectric capacity that exists in the interconnected system.

47. The proposed technical assistance and studies (Table 7.2) are either project specific in that they help prepare and/or implement specific projects, e.g., training of charcoalers for the top priority Haut Mangoro carbonization project; or they are prerequisite to energy sector planning more generally, e.g., forest inventory studies and energy sector institutional support. Virtually all the technical assistance and studies here proposed, therefore, are of immediate priority.

I. ENERGY IN THE ECONOMY

The Economy

1.1 Located in the Indian Ocean 400 km from the southeast coast of Africa, Madagascar comprises the fourth largest island in the world and a number of small island dependencies. About 63% of the total land area (587,000 km^2) is agricultural, and the climate varies from temperate in the central highlands to tropical in the coastal regions and arid in the south. With an estimated population of 9.45 million in 1983, population density is low (about 16 per km^2), which makes for relatively high delivery costs for energy, unless this is supplied from local sources. Urban population, growing at 5% annually, accounts for 19% of the total population, which is currently growing at 2.8%. Life expectancy at birth is 48 years and the adult literacy rate is 50%.

1.2 Madagascar is relatively well endowed with natural resources. It is rich in minerals such as mica, graphite and chromite and has potential for bauxite, ilmenite and iron ore. Energy mineral resources comprise petroleum, coal and uranium, as well as large tar sand and heavy oil deposits. Agriculture is well diversified. Rice is the most important food crop, followed by cassava, but Madagascar has turned from being a net exporter of rice in 1971 to an importer on an increasing scale as a result of population growth and poor yields, attributable to traditional cultivation methods and inadequate incentives to producers. Sugar cane is the biggest industrial crop, and coffee, vanilla and cloves the most important export crops.

1.3 Despite its relatively favorable resource endowment, Madagascar's economic performance has been disappointing. GDP fell almost 3% between 1972 and 1978, rose nearly 11% between 1978 and 1980, but then declined almost as sharply between 1980 and 1982, in which year it was over 3% below the 1972 level. The decline reflected a fall in industrial output of 26% over the period, which more than offset increases of around 6% in both the agriculture and services sector. There was a corresponding fall in industry's share of GDP from 19% to below 15%, while the shares of agriculture and services rose to nearly 32% (from 29%) and 34% (from 32%) respectively. The decline in industrial output was all attributable to the years 1981 and 1982 and was very largely the result of a sharp drop in imports of raw materials and spare parts, which fell by about 40% in real terms between 1979 and 1982. This in its turn reflected the foreign exchange constraint which had become dominating by that time because of the deterioration in the balance of payments (para. 1.5). There appears to have been a modest increase (about 1%) in GDP in 1983, helped by Government measures to eliminate price controls, liberalize marketing and remove administrative obstacles to the efficient functioning of the economy.

1.4 Since population has grown at about 2.6% p.a. on average in the last decade, the decline in total GDP has been accompanied by a much steeper fall in GDP per capita. In 1982, this was almost 25% lower than in 1972. An estimated 50% of the population lives below the absolute poverty level.

1.5 The balance of payments deteriorated dramatically between 1978 and 1980 and subsequently made only a partial recovery. The burden of oil imports has been an aggravating factor throughout (para. 1.9). In 1978 the Government embarked on a significantly new economic policy ("investir à outrance") of large-scale public sector investments, with greatly increased reliance on external sources of finance. Imports rose sharply in 1979 and 1980, as did investment, while public and private consumption also increased. Exports, however, were relatively stagnant, and the terms of trade deteriorated. The resulting balance of payments difficulties led to a severe reduction in imports in the years 1981-83. Imports of raw materials and spare parts were particularly affected in 1981 and 1982, causing major problems in the industrial and transport sectors, which were the main factor in the fall in GDP in those two years. Debt service obligations rose from US$19 million (4% of export receipts) to US$265 million in 1982 (72% of export receipts) before debt rescheduling. Despite reschedulings in 1981 and 1982, payments actually made in 1982 were still 30% of export receipts, and debt servicing in 1983 exceeded loan disbursements and IMF assistance. A third rescheduling became necessary in April 1984 and this, coupled with refinancing agreed by commercial bank creditors, reduced the debt service payments due from nearly 80% of export earnings to about 38%.

1.6 The medium-term economic prospects are linked to the Government's Interim Economic Program, covering the period 1984-87. This is essentially based on stabilization, rehabilitation and more efficient use of resources, with due regard to the overriding foreign exchange constraints. GDP is projected to grow at 3.4% p.a. on average in 1984-88, implying a small improvement in GDP per capita. Industrial output would grow at 4.6% p.a., essentially because of better utilization of existing capacity through greater availability of agricultural inputs and imported raw materials and spare parts, coupled with infrastructure rehabilitation. In the longer term, growth would depend on continuing improvements in the agricultural sector and on new investments.

Energy in the Economy

1.7 In common with many other developing countries, Madagascar's two main energy problems are a growing fuelwood crisis, resulting from overexploitation of the forest resources, and the total dependence on imports, virtually all in the form of oil, for its "commercial" energy, with the resultant heavy burden on the balance of payments.

Fuelwood Crisis

1.8 Wood, either in the form of fuelwood or charcoal, is the main energy source, accounting for 82% of gross energy supply in 1983. Demand for woodfuels exceeds the gross sustainable mean annual increment of forest biomass, the estimated annual deficit being about 2.3 million tons of wood equivalent (twe), or 0.72 million tons of oil equivalent (toe). The deficit is restricted to the highland provinces ("faritany") of Antananarivo and Fianarantsoa; 80% of it is in Antananarivo, which has 30% of the country's population but only about 1% of the forest area. The forest cover is being further reduced by land clearing, bush fires, and cutting and felling for various other purposes. Deforestation between 1976 and 1980 has been estimated at 165,000 ha/year and the current rate is put at 150,000 ha/year, or over 1% of the contiguous forest cover.

Import Dependence

1.9 Madagascar depends entirely on imports for its commercial energy needs. These are all in the form of crude petroleum or petroleum products, apart from relatively negligible quantities of coal (Table 1.1). Net energy imports accounted for 31% of merchandise imports in 1983 and absorbed 52% of (non-energy) merchandise export revenues. These percentages compare with figures of about 5% each in 1973 and of 13% and 15% respectively in 1978. The marked worsening of the situation after 1978 reflects the near doubling of world oil prices in 1979/81, coupled with a nearly 50% devaluation of the FMG against the US dollar between 1978 and 1983, since the volume of oil imports showed little change over the period.

Table 1.1: ENERGY AND THE BALANCE OF TRADE, 1973-83
(Millions of Current FMG)

	1973	1978	1979	1980	1981	1982	1983 a/
1. Crude Petroleum Imports	3,315	11,293	8,729	5,949	29,702	39,026	35,651
2. Petroleum Product Imports	929	2,811	5,793	9,034	5,721	18,629	27,146
3. Petroleum Product Exports	2,281	1,365	2,235	1,373	3,655	5,581	4,085
4. Net Petroleum Imports	1,963	12,739	12,287	13,610	31,768	52,074	58,712
5. Other Fuel Imports	67	196	432	404	251	476	930
6. Total Energy Imports	2,030	12,935	12,719	14,014	32,019	52,550	59,692
7. Merchandise Imports c.i.f.	45,155	99,632	135,319	126,775	156,191	197,347	193,680
8. Non-Energy Merchandise Exports f.o.b.	42,470	85,849	81,591	83,408	79,868	102,302	114,997
(6) as % of (7)	4.5	13.0	9.4	11.1	20.5	26.6	30.8
(6) as % of (8)	4.8	15.1	15.6	16.8	40.1	51.4	51.9
Exchange Rate FMG/US$	222.7	225.6	212.7	211.3	271.7	349.7	430.5

a/ Provisional.

Source: Bank economic reports, IMF reports (exchange rates).

Energy Consumption Trends

Overview

1.10 Available data on energy consumption are inconsistent and incomplete. There is no clear-cut distinction between primary and final energy consumption, different calorific values and conversion factors are used and no systematic allowance is made for fuelwood and other biomass consumption not covered by official statistics. According to mission estimates, total gross energy consumption in 1983 (excluding exports and bunker sales of petroleum products) was about 2.0 million toe (Annex 1), or 214 kgoe per capita. 82.2% of the total consisted of fuelwood, 14.2% of petroleum and products, 3.1% of hydroelectricity, 0.1% of bagasse and 0.4% of coal. About 20% of the petroleum products consumed in the form of gas oil and fuel oils were used for electricity generation.

1.11 The household sector accounts for over 83% of net energy consumption, industry for 8% and transport for 9% (Table 1.2). The dominant share of the household sector reflects the fact that households consume nearly all the fuelwood produced. As shown in Table 1.2, the sectoral pattern of commercial energy consumption is very different, transport accounting for 43% of the total, industry for 40% and households for only 16%. The transport sector's share of petroleum product consumption is even greater (59%), industry taking 27% and households 13%. The industrial sector consumes most of the electricity (72%) and households virtually all the rest.

Table 1.2: NET DOMESTIC ENERGY CONSUMPTION BY SECTOR, 1983 (percent) a/

Sector	Petroleum Products	Electricity	Coal	Total Commercial Energy	Total Energy
Industry, agriculture & others	27.2	72.0	100.0	40.0	8.0
Transport	59.0	-	-	43.0	9.0
Households	13.0	28.0	-	16.0	83.0
Total	100.0	100.0	100.0	100.0	100.0
Total ('000 toe)	241.3	78.2 b/	7.5	327.0	1,650.1 c/

Note: The figures are of direct final consumption, net of conversion losses and, in the case of electricity and petroleum products, transmission and distribution losses.

a/ Due to discrepancies and rounding up of numbers, the percentage in some cases do not sum up to 100.0.

b/ Calculated on a thermal replacement basis, 1 GWh = 250 toe.

c/ Includes 1,201.8 toe of fuelwood and 121.3 toe of charcoal.

Source: National Energy Balance. (Annex 1).

Energy Consumption and GDP

1.12 Given that 80% of Madagascar's final energy consumption consists of woodfuels whose growth responds to that of population rather than GDP, and given further that commercial energy consumption by agriculture is negligible, energy intensity and energy/GDP elasticity are here considered in terms of commercial energy consumption relative to non-agricultural GDP (Table 1.3). The resultant coefficients show somewhat erratic movements. Over the 1976-83 period as a whole, energy/GDP elasticity works out at 1.3 and energy intensity (toe/million of real GDP) slightly declined which, in the circumstances, seems plausible enough. However, between 1976 and 1979 when real (non-agricultural) GDP increased, energy/GDP elasticity appears to have actually been negative (-0.3) and energy intensity significantly declined (by 14%). Conversely, during 1979-83 when real GDP substantially declined, energy intensity considerably increased and energy/GDP elasticity turned back positive but only to 0.6. It is difficult to see any analytical value in these coefficients except that over a sufficiently long period (1976-83) commercial energy/non-agricultural GDP elasticity is seen to be significantly greater than 1, as one would expect to be the case in a developing country like Madagascar; however, the mission does not consider this coefficient's apparent value of 1.3 as solid enough for use in projections of future aggregate energy demand.

Table 1.3: COMMERCIAL ENERGY CONSUMPTION a/ AND NON-AGRICULTURAL GDP, 1976-1983

	1976	1979	1983	1976-79	1979-83	1976-83
				-- (% growth p.a.) --		
Net Domestic Consumption, '000 toe	407.5	392.6	327.2	-1.2	-4.5	-3.1
Consumption per capita, kgoe	52.1	46.3	34.6	-3.9	-7.0	-5.7
Non-agricultural GDP, billion 1970 FMG	175.6	196.7	147.7	3.9	-6.9	-2.4
GDP per capita, '000 1980 FMG	77.3	78.8	66.0	0.6	-4.3	-2.2
Energy per million 1970 FMG of non-agricultural GDP, toe	2.32	2.00	2.22			
Energy/non-agricultural GDP elasticity				-0.3	0.6	1.3

a/ Excludes jet fuel which is sold to international carriers.

Source: IBRD (for GDP), SOLIMA, and Annex 29.

Energy Resources

Overview

1.13 Madagascar has significant potential energy sources, both renewable and non-renewable. The known non-renewable sources comprise solid fossil fuels (coal, lignite and peat), heavy oil and tar sands. Prospects for petroleum are regarded as promising. Although no uranium resources have so far been defined, the geological conditions are considered favorable in several areas. The main renewable energy sources comprise fuelwood, agricultural and animal residues, hydropower, solar energy and wind energy. There is also some geothermal potential. The energy potential of the seas surrounding Madagascar is not likely to be of interest in the foreseeable future.

Solid Fossil Fuels

1.14 The existence of coal in southwestern Madagascar has long been known. The area of greatest interest is the Sakoa basin, with estimated geological reserves of 1,000 million tonnes and mineable reserves of moderate ash, medium volatile steam coal estimated at 173 million tonnes, of which 82 million tonnes are recoverable by underground methods. According to other estimates, 23 million tonnes could be recovered by open-pit methods.

1.15 The principal lignite resources occur in the Antsirabe region of the central highlands. According to the most recent estimate, proved reserves are 11 million tonnes, probable reserves 10.6 million tonnes and possible reserves 32 million tonnes. The lignite is not of prime quality and open-pit mining is not feasible. It appears to have no economic potential for the foreseeable future.

1.16 Peat occurrences are widely reported and peat is used on a small scale as a fuel for brick production. The peat resources have not been investigated, but there appears to be potential for significant discoveries.

Petroleum

1.17 Madagascar has long been known as a country with prospects for commercial oil or gas discoveries (Annex 2). All the elements for oil generation and accumulation exist to some degree, as indicated in Annex 2. Two sedimentary basins, Morondava in the west and Mahajanga in the north, are prospective for oil and gas. Their total land area is 170,000 km^2, with a further 80,000 km^2 offshore at depths up to 200 meters; the deep water area (200-2,000 meters) covers another 50,000 km^2, which may be found to be prospective in the future. Most exploration has been in the Morondava basin, where the tar sand and heavy oil shows have been found (para. 1.18). During exploration in the period 1965-74 by five major oil companies and six independents, favorable stratigraphy and hydrocarbon shows (both oil and gas) were encountered, but by 1975 most of the companies had departed to concentrate on the successful finds in the North Sea and Far East. Following the oil price increases of 1979, the Government embarked on a vigorous campaign to promote exploration, with technical assistance under the first IDA petroleum credits. The results have been highly encouraging. Four major companies (Mobil, Occidental, AGIP and Amoco) are now engaged in active exploration, and by November 1984 had spent US$90 million, which was far in excess of their contract obligations. By mid-1988, they are expected to spend nearly US$100 million more.

1.18 There are known tar sand and heavy oil deposits in western Madagascar (Annex 2). The Bemolanga tar sands are estimated to contain 5-20 billion barrels of oil equivalent. However, studies partly financed by IDA have indicated that their exploration would not be economic with current technology and expected oil prices. The heavy oil deposits at Tsimiroro are being investigated with IDA financing to determine whether there are any areas with sufficient oil saturation (over 60%) to attract exploration by private oil companies.

Uranium

1.19 Uranium-bearing minerals were first discovered in Madagascar in the late 1940s and some small-scale mining, subsequently abandoned, was undertaken. Exploration has been intensified since the late 1970s, with the assistance of the United Nations Development Program (UNDP) and the International Atomic Energy Agency (IAEA). About US$5 million was spent on surveys and surface drilling between 1977 and 1983. No uranium resources have been identified fitting the IAEA's categories, 5/ but there are numerous geological environments where such resources could be found, and exploration is continuing.

Hydropower

1.20 The hydropower potential of Madagascar has not been fully evaluated, but it is very large and widely distributed. According to the most recent JIRAMA estimates, there are 339 known sites with power output

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5/ The IAEA resource categories comprise: (i) Reasonably Assured Resources (RAR), defined as those which have a high assurance of existence; (ii) Estimated Additional Resources - Category I (EAR-I), referring to uranium additional to RAR that is expected to occur, but with less certainty than RAR; (iii) Estimated Additional Resources - Category II (EAR-II), which are expected to occur in addition to EAR-I, but for which the estimates are less reliable; and (iv) Speculative Resources (SR). The resources in each category are further classified into three production cost categories, viz. less than US$80/kg uranium metal (U), US$80-130/kg U and US$130-260/kg U (US$ of January 1, 1984).

potential of 7,055 MW 6/ and an annual production capability of nearly 60,000 GWh. Thirty-three sites with estimated power outputs above 50 MW account for 6,330 MW (90%) of the total, but there are 72 sites in the 1-5 MW range and over 200 sites below 1 MW. Only 115 MW (1.6%) of the known potential has been developed.

Fuelwood

1.21 The contiguous natural forest cover is estimated at 12.3 million hectares to which should be added 265,000 hectares of dedicated plantations. Assuming that only 20% can be exploited for fuelwood in the long term, the estimated annual sustainable yield is about 2.0 million toe. This compares with total gross supply of 1.7 million toe in 1983. However, the overall surplus of 0.3 million toe results from a deficit in Antananarivo and Fianarantsoa of some 0.6 million toe and a combined surplus in the other four provinces of 0.9 million toe. Since it is not economic to transport wood from the surplus to the deficit provinces, the effective annual deficit is 0.6 million toe.

Biomass Other Than Wood

1.22 Madagascar produces many agricultural residues with potential use as fuel. The most important is rice husk, with estimated production (1984) of 4.6 million tonnes (1.4 million toe). Its only use at present is as fuel for steam boilers to provide mechanical shaft power in some rice mills, but it could be briquetted to provide fuel for households and industry. Sugar bagasse and cane field residues (estimated 1984 production 1.2 million tonnes, or 89,000 toe) are the other potentially important energy source for the production of electricity for local communities to displace diesel power generation (bagasse is already used within the sugar industry for the production of process heat and electricity). Most of the other agricultural residues are too scattered under the present mode of production, or have higher alternative uses, to be of interest as fuels.

1.23 Animal residues, mainly from the large population of zebu cattle (8 million head), represent another substantial potential energy source, estimated at 2 million toe in 1977.

Solar and Wind Energy

1.24 Because of its favorable geographical location, Madagascar enjoys high levels of insolation. The available data, collected over a 30-year period at some 30 stations, show that average hours of sunshine range from 2,000 hours in the northeast to 3,600 hours on the southwest coast, resulting in a very large annual energy potential ranging up to

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6/ The installed capacity would be two to three times higher.

over 2000 kWh/m^2, particularly on the west coast. Preliminary studies indicate a wind energy potential varying between 200 and 2700 kWh/m^2/year at 10 meters above ground level, but these results are based on analysis of only a small part of the available data, which cover a period of 25 years at 30 locations. Wind energy has been utilized for a long time in the southern part of the country for water pumping and irrigation, but further research is needed to determine the scope for other applications.

Geothermal Energy

1.25 An initial appraisal of national geothermal resources was made in 1979. Eight sites were identified with geothermal temperatures sufficiently high (above 150°C) for power generation and industrial steam supply (Antsirabe, Itasy, Miandrivaka, Ambilobe, Ambanja, Andapa Doany, Nosy Be and Morondava). More detailed surveys are under way. However, the economics of geothermal resource development look doubtful because of (a) the relatively great depth of the resource; (b) the need for a minimum demand of 20 MW at each site to justify the large initial investment; and (c) the existence of many competing energy resources, especially hydropower, which are reasonably accessible and probably cheaper. There is little justification therefore for actively pursuing geothermal development except in regions with limited hydropower potential where large, economically viable encl..ve industries, such as mining, are expected to develop.

Energy Policy

1.26 The fundamental objective of national energy policy, as defined in the 1981 law on the second national economic plan (1982-87), is energy independence through the substitution of indigenous energy sources for imported oil. A complementary objective is to arrest and ultimately to reverse the present deforestation. The proposed strategy for achieving these objectives aims at tackling the problem from both the demand and supply sides. On the demand side, the emphasis is on an intensified energy conservation campaign to reduce consumption through increasing the efficiency of utilizing all forms of energy, but particularly wood and petroleum products. Conservation is regarded as especially important for restraining demand during the transition period before the supply side of the strategy, based on a balanced development of national energy sources, achieves the objective of substituting these for imported oil. The Government strategy, as defined in the 1982-87 plan, envisages an important role for indigenous energy sources not merely in eliminating the present adverse energy balance of trade, but in converting it into a favorable balance through the export of coal, uranium and, it is hoped, oil.

Future Energy Demand

1.27 Table 1.4 summarizes the detailed projections of final energy consumption by energy form and sector in 1995 and compares these with the corresponding figures for 1983. Total energy consumption is seen to increase over the 12-year period from 1.65 million toe to 2.44 million toe or by 3.3% p.a., which is considerably above the current population growth rate of 2.8% p.a. The difference is due mainly to rather higher growth rates of energy consumption in industry (5.7%) and transport (4.3%); as a corollary, the consumption of petroleum products and electricity is projected to increase by 4-5% p.a. and that of coal by even 13% p.a., this latter figure reflecting the projected increase in cement production. Significantly, however, the great bulk of final energy consumption -- 76% in 1995 vs. 80% in 1983 -- will continue to consist of woodfuels, practically all of which are used to meet basic household needs. Given the already existing shortage of woodfuels and the resultant deforestation, these numbers highlight the fact that Madagascar's main energy problem is the supply of, and the management of demand for household fuels. Chapter II addresses the relevant issues and options in some depth and develops the building blocks for a household energy strategy.

Table 1.4: FINAL ENERGY CONSUMPTION BY ENERGY FORM AND SECTOR, 1983 AND 1995

Energy Form/Sector	Consumption 1983	Consumption 1995	Percentage of Total 1983	Percentage of Total 1995	Annual Growth Rate 1983-95
	-- ('000 toe) --		-- (%) --		
Woodfuels	1,323.1	1,854.4	80.2	76.1	2.9
Fuelwood	(1,201.8)	(1,642.0)	(72,8)	(67.4)	(2.6)
Charcoal	(121.3)	(212.4)	(7.4)	(8.7)	(4.8)
Petroleum Products	241.3	411.0	14.6	16.9	4.5
Electricity	78.2	135.7	4.7	5.6	4.7
Coal	7.5	34.0	0.5	1.4	13.4
Total	1,650.1	2,435.1	100.0	100.0	3.3
Households	1,375.1	1,935.8	83.3	79.5	2.9
Transport	141.4	233.8	8.6	9.6	4.3
Industry and Others	133.6	265.5	8.1	10.9	5.7

Source: Annexes 22, 30.

II. RENEWABLE ENERGY SOURCES

2.1 Wood, in the form of firewood or charcoal, is the main energy source in the country, accounting for about 82% of gross energy consumption (para. 1.10). The first part of this chapter therefore deals with the main issues and options relating to the supply and consumption of fuelwood. The second part covers the other main renewable energy sources of biomass other than wood, small-scale hydropower (i.e., 1 MW and below), solar energy and wind energy.

Fuelwood

Fuelwood Supply

2.2 There is general recognition in Madagascar of the dearth of appropriate forest resource data, but the official estimate of about 12.8 million hectares is widely accepted (Table 2.1). If it is assumed that only 20% of the remaining high forests are able to come under long-term sustained exploitation for timber and fuelwood, and that their productivity under a good management regime will be 3 m^3/ha/year; that the sustainable productivity from mangroves is 2.8 m^3/ha/year; and that the yield of eucalyptus and pine plantations is 10 and 2.7 m^3/ha/year respectively, then the gross sustainable mean annual increment (mai) of woodfuels is approximately 2.0 million toe, as shown in Table 2.1. The location of the main accessible resources is shown in the chart in Annex 23.

Fuelwood Consumption

2.3 Total final consumption of fuelwood in 1983 was estimated at about 5.3 million tons wood equivalent 7/ (twe), or 1.7 million toe. Of the total, about 72% was consumed as firewood and the rest in the form of charcoal. Charcoal is consumed very largely in urban areas. Average fuelwood consumption per capita nationwide was 559 kgwe (173 kgoe), but the comparative figures for urban and rural consumers were 210 and 550 kgwe respectively in the highlands (Antananarivo and Fianarantsoa provinces) and 170 and 365 kgwe in the lowlands (the remaining four provinces). The higher consumption of the highland population presumably reflects occasional space heating demands in the winter months.

7/ "Wood equivalent" is wood at 25% moisture content wet basis (mcwb) per unit weight. 1 twe = 0.31 toe.

Table 2.1: CONTIGUOUS FOREST COVER AND SUSTAINED YIELD NATIONALLY, 1985

Province	Forest	Mangrove	Plantations Eucalyptus	Plantations Pine	Total Forest Cover		Mean Annual Increment(MAI) Gross (MAI)			Trends in Gross MAI 1985	1990	1995	2000
	('000 hectares)					%	('000 m^3)	('000 twe)	('000 toe)	('000 toe/year)			
Antananarivo	114.5	0.0	52.8	8.1	175.4	3	619	376	117	117	107	99	91
Fianarantsoa	1,285.0	0.0	40.2	37.4	1,363.6	13	1,274	818	254	254	247	240	234
Total Uplands	1,399.5	0.0	93.0	45.5	1,538.0		1,893	1,194	370	370	354	339	325
Antsiranana	1,504.3	30.0	5.5		1,539.8	34	1,041	688	213	213	212	211	211
Mahajanga	2,127.4	137.0	6.7		2,271.1	14	1,724	1,124	348	348	347	346	345
Toamasina	2,813.7	0.0	22.1	80.0	2,915.8	41	2,125	1,393	432	432	428	424	421
Toliary	4,462.0	51.0	11.9		4,524.9	27	2,938	1,950	605	605	602	601	599
Total Lowlands	10,907.4	218.0	46.2	80.0	11,251.6		7,828	5,155	1,598	1,598	1,590	1,582	1,576
General Total	12,306.9	218.0	139.2	125.3	12,789.6	21	9,721	6,350	1,968	1,968	1,943	1,921	1,901

Source: Mission estimates.

Table 2.2: FUELWOOD CONSUMPTION, 1983
('000 tons wood equivalent)

	Highlands	Lowlands	Total
Firewood	3,344	1,482	3,826
Charcoal	1,147	362	1,509
Total	3,491	1,844	5,335

Source: FAO/CP and mission estimates.

2.4 Comparing the sustainable supply with demand (Table 2.3), it will be seen that if the figures for the individual provinces are summed, there was an apparent national surplus in 1983 of 293,000 toe. However, in the highlands provinces of Antananarivo and Fianarantsoa there was a large deficit, nearly 70% of it in Antananarivo, which has 30% of the total population but only 1.4% of the forest cover. Some limited woodfuels transfer can be done between Antananarivo and Toamasina provinces due to the particular location of the capital city. Other than that, no economic transport can take place at present woodfuel prices. Taking into account the share of Toamasina's resource that is accessible from Antananarivo, the net deficit from the highlands provinces can be estimated at 600,000 toe/year or 1.9 million twe/year.

2.5 From Table 2.3 it is clear that the focus of the national fuelwood problem is in the hinterland of Antananarivo, where the gap between supply and demand is wide and growing. Between 1985 and 1995, if no corrective action is taken, the gap is projected to increase by nearly 65% to about 2.2 million twe (680,000 toe), as shown in Annex 3. The implications are that existing forest stocks are being seriously "mined" and that much more serious problems of fuel supply in the province are imminent. Recent price trends for fuelwood and charcoal confirm this (para. 6.11), as does the growing use of rice straw, hitherto regarded with disdain, as cooking fuel.

Deforestation

2.6 The annual rate of deforestation is estimated to have been 165,000 hectares between 1976 and 1980 and to be continuing at the rate of 150,000 hectares a year. 8/ If these estimates are correct, contiguous forest cover would decrease by 1.5 million hectares, or about 12% over the next ten years. The economic and social consequences will be grave. Erosion, already a serious problem in the highlands, will

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8/ The main factors in deforestation are land clearing for food crop production, bush fires and cutting and felling for various other purposes. FAO Tropical Forest Resources Assessment Project, 1981.

increase, resulting in decreased soil fertility, reduced water catchment regulation, siltation of irrigation systems, and reduction in overall carrying capacity for agricultural ecosystems. In addition, the time spent gathering firewood will increase for rural dwellers, decreasing the economic productivity of labor in rural areas. In consequence, the price of woodfuels can be expected to increase greatly in real terms (para. 6.9).

Table 2.3: FUELWOOD SUPPLY AND DEMAND, 1983 ('000 toe)

Province	Sustainable Accessible Supply	Firewood	Charcoal a/	Total	Deficit	
		---- Demands	----		('000 toe)	('000 twe)
Antananarivo	243.9	393.4	269.6	662.9	419.0	1,334.2
Fianarantsoa	253.7	343.0	91.2	434.2	180.5	574.8
Antsiranana	213.2	70.5	27.8	98.3	(114.9) b/	
Mahajanga	348.4	102.9	28.1	131.0	(217.4)	
Toamasina	304.5	150.2	31.8	182.0	(122.5)	
Toliary	604.6	141.9	25.2	167.1	(437.5)	
Total	1,968.3	1,201.9	473.7	1,675.6	(292.7)	1.909.0

a/ Charcoal is accounted for at its primary energy equivalent, i.e., 8.9 tons of 25% mcwb wood per ton of charcoal and 1 twe = .31 toc.

b/ Deficit figures in brackets indicate non transportable "surpluses" which have not been accounted for in the total deficit. Note that the woodfuels supply for Antanarivo includes forests and plantations in Toamasina.

Source: Mission estimates and consultation with senior foresters in GOM.

Subsector Strategy

2.7 There are two key objectives of a household energy strategy in Madagascar: the least-cost supply of cooking fuels and, consistent with this objective, reducing the pressure of fuelwood scavenging on the remaining forest resources in heavily populated zones. Components of the strategy should include augmenting the supply of both woodfuels and other fuels, such as electricity, for household cooking, as well as reducing demand in relative terms by improving cooking efficiency. Even if it were the most economic solution, afforestation alone is not the answer. To meet the present deficit, there would have to be in place, and producing now, the equivalent of an additional 140,000 ha (at 20 m^3 mai), plus the equivalent of at least 10,000 ha per year of additional afforestation to keep pace with the growing fuelwood demand, let alone that required for protection of water catchments, soil erosion control and timber products. Although the GOM has demonstrated a capability of large-scale plantation development (80,000 ha in 15 years by Fanalamanga), the lead time from design to production on an energy forestry program can be up to 10 years, and as noted below (para. 2.13), plantation-grown fuelwood is double the present market price. On the other hand, the rate of tree planting by small-holders or communities is presently very small in comparison to the need, and although this may be a cheap alternative, significant institutional and sociological barriers remain to scaling up this effort. Hence, afforestation can be only one part of a multifaceted household energy strategy which addresses both supply and demand issues, seeking to augment cooking supplies and at the same time to increase the efficiency of consumption by demand management.

Increasing Supply

2.8 An effective strategy for increasing fuelwood supplies must combine long-term measures, based on plantation development, with short- to medium-term measures designed to produce results in the next 5-7 years by increasing the productivity of the existing fuelwood plantations on the one hand and increasing the recovery and conversion of currently available resources on the other.

Short-term Supply Options

2.9 The short-term supply options comprise the following:

(a) Improving Coppice Management. Many of the fuelwood plantations are old and have been coppiced at least five times (Annex 4). Under the present pattern of exploitation, there is no system of plantation management. This results in lower yields and greater susceptibility to disease. Trimming of the coppice regrowth to two or three of the strongest shoots after 3-6 months should lead to about 25% increase in yield of fuel quality biomass. The fuelwood plantations concerned may also be so old, and have lost so many of the orginal trees, that the economic viability of enrichment or replanting may also need to be examined.

(b) Exploiting Underutilized Forest Resources. Permits are issued by the Directorate of Fisheries and Forests (DEF) for timber extraction from native forests, virgin or degraded, and long-established plantations. The present method of exploitation, whereby a maximum of 40 m^3 of logs are extracted selectively from upwards of 500 m^3 per hectare, results in retrievable but unutilized fuelwood quality material estimated by the mission at 100 m^3 per hectare on average. The 2~,000 hectares at present under exploitation could conceivably yield 2.7 million m^3/year (about 1.8 million twe, or

0.55 million toe) of fuelwood, or about one-third of present national demand. The mission estimates that under optimal circumstances up to one-third of this could be recovered within the next six years and over one-half within the next decade. However, only a small proportion is accessible at present because of poor roads and lack of transportation; the nature of the permits and institutional arrangements in the forestry sector give no incentive to recover even the accessible portion; and most of the material would have to be carbonized for there to be some prospect of its economic delivery to the nearest urban markets. Thus, in projecting future supply of household fuels only 1.35 million twe is regarded as being ultimately recoverable and only 40% of this resource is regarded as having been retrieved by 1995 (i.e., 540,000 toe/year or about 81,000 tonnes/year of charcoal).

(c) Recovery of Sawmill and Wood-processing Wastes. Timber processing commonly produces large quantities of unrecovered fuel quality residues. The mission estimates that recovery of dressed lumber on average is 35% of log input volume and that loose bark, sawdust and shavings will comprise 30%, and offcuts and slabs 35%, respectively. The annual log input volume is estimated at 130,000 m^3/year, hence about 45,000 m^3 is available as offcut and slabs, which the mission believes can be carbonized to produce up to 5,600 tonnes of charcoal for urban markets with favorable economic returns. Market prices of woodfuels will have to increase substantially for it to be financially attractive to recover finer wastes such as sawdust and shavings. But since substantial real increases are likely within the decade, there is justification for small-scale trials of recovery systems, such as briquetting presses, to establish their firm costs and logistics within the next three years.

(d) Improved Carbonization Efficiency. Charcoal is produced almost entirely by traditional above-ground earthen kilns. The average charcoal yield is probably about 15% of the oven dry weight of the charge, and the net returns to labor are marginally below the average daily wage of unskilled workers (Annex 5). Improved types of kiln would give much better yields. These are: (i) a modified traditional kiln ("meule casamance"), which would raise the efficiency of the present type by at least one-third and the return to labor by some 50% (Annex 6); (ii) the "Ghana" type of portable metal kiln costing about US$800, with an efficiency of about 25%; and (iii) fixed brick kilns of the "meule beninois" (below-ground) or "meule ougandais" (above-ground) type, both of which have been thoroughly tested by DEF. The latter are made of almost entirely local materials and have efficiencies of 20-25%. However, their application is limited to locations where suitable wood residues are continuously generated (e.g., at sawmills), since it is unlikely, practical or economic to build them for intermittent use in plantations which are harvested on several years' rotation.

(e) Carbonization of Haut Mangoro Pine Smallwood. There are vast potential wood resources in the Fanalamanga managed plantations near Moramanga (130 km east of Antananarivo). These resources are mainly composed of:

- the thinnings from the main plantations (65,000 ha),
- the clearcutting of the "stunted" pines (15,000 ha),
- residues from future logging operations,
- future sawmill residues,
- possible harvest from some eucalyptus plantations.

All these resources can be used as raw material for woodfuels production. An assessment of these resources is being performed by the Bank as part of the preparation of Forestry III Project. A UNDP financed study was conducted to review the feasibility of a wood pellet and charcoal plant for the same Haut Mangoro area. The study estimated that a constant supply of 191,000 m^3 per annum could be obtained from the various resources, among which:

- a minimum of 90,000 m^3/year from the thinnings,

- 54,000 to 108,000 m^3/y from the clear cutting of the stunted pines, according to the rate of development of the activity (a total of 540,000 m^3 to be cut in 5 or 10 years).

Given the present state of knowledge, and for the sake of homogeneity of the data, the above estimate of 191,000 m^3/year was assumed as representing the constant flow of raw material that could be processed.

2.10 To use this resource the UNDP study recommended the construction of a plant producing 22,600 t/y of wood pellets and 15,900 t/y of charcoal. The Sandwell feasibility study concludes that the economic rate of return is 21% and the financial rates of return 16% and 6%, before and after taxes.

2.11 It is the mission's opinion that the proposed wood pellet pine-chip and charcoal plant is an impractical and expensive option for the use of the Haut Mangoro resource and that smallholder and/or semi-centralized lump charcoal production is the most attractive alternative. This finding is based on the mission's comparative analysis of these alternatives provided in Annex 7. In the alternatives examined there, lump charcoal production would average about 21,500 tonnes/year, with 15,900 t/y being sold to CIMA and 5,600 t/y being used in households.

The salient points arising from the comparative analysis were that:

(a) the selling price of charcoal has been substantially overestimated in the UNDP study, mainly because of very favorable assumptions on the transport costs. An ex mill price of charcoal of 96 MFG/Kg for selling to the cement factory in Antsirabe seems more appropriate than the price of 141 FMG/Kg selected in the UNDP study; and

(b) using the same economic parameters, the lump charcoal alternative was found to have a far higher rate of return on investment as shown hereafter, in financial terms (million 1984 FMG):

	Local Charcoalers	UNDP Study	Notes
Capital		1.1	8.4First three years
Labour (man year)	564	437	Average production year
P.V. of Net Cash Flow	11	0	At 10% discount rate
IRR	92%	10%	

Source: Mission estimates and UNDP.

2.12 Given these preliminary results, the mission recommends that:

(a) a detailed feasibility and design study for the production of lump charcoal by smallholders and/or in semi-centralized medium-scale kilns should be conducted and that small-scale kilning of thinnings begin on a field basis as soon as possible; and

(b) that the Government does not proceed with the Sandwell project proposal at this stage. 9/

Long-term Supply Options

2.13 In addition to the above measures to increase supply in the short- to medium-term impact, there are other supply options which,

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9/ As of 1986, the Government is interested in pursuing small-scale lump charcoal production. In fact, terms of reference have been finalized for a feasibility study on decentralized small-scale kilns. In addition, it seems likely that the resources involved are far greater than was thought, on the order of 400,000 m^3 per year from thinnings. Converting this entirely to charcoal would yield about 40,000 tonnes annually, almost as much as the entire consumption of Antananarivo.

because of the long lead times involved, will have little impact within a decade but may add greatly to supplies thereafter. Pre-investment analysis or project implementation would need to commence now in order to realize the long-term benefits of any programs of afforestation shown to be economically and financially viable. The most important of the options to be evaluated are centralized peri-urban plantations, urban reforestation and rural afforestation.

(a) Centralized Peri-urban Plantations. Plantation-grown firewood could become economically the least-cost energy source for household cooking if an efficient metal wood-burning stove can replace open fires. However, the financial viability at present market prices for charcoal of large-scale fuelwood plantations located at great distances from urban markets in Madagascar has yet to be demonstrated. A basic inventory of forest cover and effective land-use planning would be essential prerequisites of a national fuelwood plantation investment program.

(b) Urban Reforestation. Scavenging for fuelwood in urban areas, whether for household use or brickmaking, is common practice. In particular, the low-lying swampy areas within or near the city boundaries of Antananarivo have been largely denuded of trees. These several thousand hectares of swamp land, where neither nutrients nor moisture is limited, offer a unique opportunity for sustained high yields of fuelwood for urban households and the smallholder brick industry. The main constraints to reforestation are likely to be land tenure and user rights. In the case of publicly owned land, acceptable arrangements would have to be made for leasing small parcels to families residing nearby.

(c) Rural Afforestation. Although the Government recognizes the need for rural afforestation and has submitted to donors for funding a program of "micro-boisement" for several regions, present efforts are minimal; the administrative arrangements for extension work are weak, and skilled manpower, transportation and basic infrastructure requirements are strictly limited. Well planned and executed tree-planting at the village/farm level and protection of remaining forests and dispersed tree cover in the vicinity of intensively cultivated areas are essential not only for sustained fuelwood supply, but also for sustained agricultural production. In the short-term, there is some scope for improved production and distribution of appropriate tree species. However, any larger scale programs need to be based on a proper understanding of the socio-cultural and environmental constraints of target areas. They can only hope to succeed if forestry sector institutions are greatly and permanently strengthened with technical assistance for planning, management and localized skill-training.

2.14 In order to facilitate the implementation of new programs of afforestation:

(a) in the event a sizeable fuelwood plantation program is shown to be viable, the Government should designate a commercial fuelwood plantation agency in the critical fuelwood deficit zones. Fanamalanga, which has proven itself a competent plantation development institution (para. 2.26), should be seriously considered for this role, at least for the province of Antananarivo, in addition to its established role in production of commercial timber;

(b) the Government should seek to maximize the involvement of the private sector in fuelwood production, with large and small entrepreneurs leasing plantations for exploitation, after Fanalamanga has developed them to the point of first harvest; and

(c) Fanamalanga should expand its program of research and development on new fuelwood species and provenances to include all reasonable treatments of spacing, fertilization and rotation, with the object of improving fuelwood plantation design and yields. Fanamalanga should also be encouraged to expand its experimental program of planting on the vast unforested slopes within its concession area, and it should be equipped with a data base and management information system to interpret the results of all this research work for early commercial application.

Demand Management

2.15 Demand management aims to relieve the pressure on existing fuelwood resources by reducing per capita demand. Few, if any, of the numerous options for doing this have yet had a demonstrable impact on fuelwood demand in developing countries. Hence, it would not be prudent to project a fall in demand, and hence in the need for supply-side investment, as a result of the demand management measures identified here, until significant demand reductions have been clearly demonstrated. For this purpose, the present data base on household energy consumption in Madagascar is sorely in need of improvement.

2.16 Woodfuel prices in Madagascar are uncontrolled and in the socio-economic circumstances practically uncontrollable; thus, reducing the demand for woodfuels by raising their prices is not a realistic option. The remaining two options to this end are basically: (a) increasing cooking efficiency; and (b) substituting other energy sources, whether traditional, such as agricultural residues, or modern, such as kerosene or electricity, for fuelwood. Table 2.4 presents the comparative financial and economic costs of cooking fuels in

Antananarivo, 1984 and indicates the scope for reducing household energy demand by more efficient cooking appliances.

Table 2.4: COMPARATIVE COST OF HOUSEHOLD ENERGY FORMS, ANTANANARIVO, LAST QUARTER, 1984

Fuel	Price	Energy	Energy Value	Price	PHU	Cost of Energy Utilized
	(FMG)	(Unit)	(MJ/unit)	(FMG/MJ)	(%)	(FMG/MJ)
Electricity						
Tariff	91.1	kWh	3.6	25.3	60	42.2
SRMC	12.0	kWh	3.6	3.3	60	5.6
LRMC	50.0	kWh	3.6	13.9	60	23.2
LRMC I	50.0	kWh	3.6	13.9	80	17.4
LPG						
Fin.	520.0	kg	45.6	11.4	45	25.3
Econ.	319.2 a/	kg	45.6	7.0	45	15.6
Kerosene						
Fin. I	160.0	liter	35.0	4.6	35	13.1
Fin. II	160.0	liter	35.0	4.6	45	10.2
Econ. I	151.3 a/	liter	35.0	4.3	35	12.4
Econ. II	151.3 a/	liter	35.0	4.3	45	9.6
Charcoal						
- from firewood						
Fin. I	55.0	kg	29.0	1.9	24	7.9
Fin. II	55.0	kg	29.0	1.9	30	6.3
Econ. I	108.0	kg	29.0	3.7	24	15.5
Econ. II	108.0	kg	29.0	3.7	30	12.4
- from rice husk briquet						
Fin. I/Econ. I	75.0	kg	25.0	3.0	24	12.5
Fin. II/Econ. II	75.0	kg	25.0	3.0	30	10.0
Firewood						
Fin. I	22.0	kg	14.3	1.5	13	11.8
Fin. II	22.0	kg	14.3	1.5	25	6.1
Econ. I	29.0	kg	14.3	2.0	13	15.6
Econ. II	29.0	kg	14.3	2.1	25	8.1
Rice Husk Briquets						
Fin./Econ. I	13.0	kg	15.6	0.8	13	6.4
Fin/Econ. II	13.0	kg	15.6	0.8	25	3.3

Notes: PHU - percentage heat utilized; Fin. - present market price; Econ. - estimated economic cost; Fin. I - means present market price with the assumption that present stoves or open fire are used; Fin. II - means present market price with the assumption that improved stoves and electric rice cookers are used; Econ. I - means estimated economic cost with the assumption that present stoves or open fire are used; Econ. II - means estimated economic cost with the assumption that improved stoves and electric rice cookers are used; LRMC I - means long run marginal cost applicable with improved electric rice cookers. The table assumes an electricity load pattern similar to current conditions.

a/ C.i.f. cost (Table 6.1) plus 5% for domestic transport and handling charges.

Source: Mission estimates and field calculations.

Increasing Cooking Efficiency

2.17 Improved cooking efficiency should be achievable over the short-to-medium term as follows:

(a) Improved Woodfuel Stoves. Introduction of improved charcoal and wood stoves is the main option. The Madagascar charcoal cooker is of a typical African design, which Bank work elsewhere indicates could, with minor changes, be made 25% more fuel-efficient. Portable metal wood stoves which consume up to 50% less fuel than open fires are being introduced on a pilot basis in Ethiopia with Bank assistance. Only actual operation in Madagascar conditions will show whether the estimated fuel savings are achievable in practice.

(b) Improved Modern Fuel Stoves. Kerosene stoves currently available in Antananarivo cost about US$20 and are relatively inefficient. Modern multiple wick kerosene stoves of Indian design, such as the Ashok 7 or Nutan stove, are 20-30% more efficient and could be made locally or imported for US$5-10. Suitably designed electric rice cookers could also reduce the economic cost of electric cooking to competitive levels with charcoal and kerosene, at least on the basis of the shortrun marginal cost of electricity.

Interfuel Substitution

2.18 Combining possible improvements in cooking efficiency with a comparative cost analysis of woodfuel substitutes (Table 2.4) provides the following results. In terms of financial cost, charcoal (from firewood) was the cheapest (7.9 FMG/MJ) where traditional stoves are used (Table 2.4). With improved stoves, however, firewood comes out on top (6.1 FMG/MJ), closely followed by charcoal (6.3) and rice husk briquettes (6.4). None of the modern fuels — electricity, LPG, kerosene — could even remotely compete. A rather different picture is obtained, however, in terms of comparative economic cost. In this perspective, and again with the use of improved cookers, rice husk briquettes — yet to be developed on a commercial scale — clearly would have been the cheapest cooking fuel (3.3 FMG/MJ), followed by electricity (5.6) if priced at short run marginal cost (because of the existing substantial excess hydro capacity), firewood produced from nearby peri-urban plantations and burned in portable metal stoves (8.1), kerosene (9.6) and charcoal burned in improved charcoal stoves (12.4). Thus, from an economic point of view, kerosene begins to look attractive as an efficient woodfuel substitute, especially since common acceptance of improved kerosene stoves is likely to be more readily obtained than for improved wood and charcoal stoves.

2.19 The substitution options with a short-term impact are:

(a) Use of Rice Husks. The main crops of potential interest are listed in Annex 8. The only one with commercial potential in the short-term is rice husk, produced in the main rice-growing basin, Lac Aloatra, and around major urban centers, particularly Antananarivo. The only use at present is in husk-fired steam boilers for mechanical shaft power production. The very large resource of the Lac Aloatra region is not yet economically accessible, but there are good prospects for the economic production of rice-husk briquettes as household fuel in the vicinity of Antanarivo. Some 17,000 tonnes/year of rice husks are produced there (Annex 9), the equivalent of 20,000 twe, or 5% of Antananarivo's current fuelwood supply. Preliminary cost data suggest rice husk briquettes could be produced for retail at 60% of the present price of firewood (Annex 10).

(b) Expanded Use of Modern Fuels. In the longer term, much more substitution of modern fuels must occur as it becomes increasingly difficult to meet the growing demand for firewood and charcoal (para. 2.5). Even in the short-term, opportunities exist for greater use of electricity and kerosene. In the Antananarivo region, there is a large surplus (320 GWh) of hydroelectricity (para. 4.12), 10/ the economic cost of which is solely the cost of new or reinforced distribution, estimated at about US¢2/kWh. Kerosene is only slightly more expensive than firewood at current market prices (para. 6.10) and could become cheaper if improved kerosene stoves are encouraged (para. 2.14(c)). As an illustration of the possible impact of substitution, if 10% of the approximately 100,000 households in Antananarivo substituted kerosene, and 10% electricity, for charcoal, demand for charcoal would decrease by 22,500 tonnes/ year, or about 200,000 toe. The requirements to achieve this reduction would be a relatively modest 4,600 tonnes of kerosene and 30 GWh of electricity. If 120 GWh of electricity and 9200 tonnes of kerosene were substituted for charcoal, the need for dedicated fuelwood plantations and rural afforestation would be reduced by 14,000 and 19,000 hectares respectively.

2.20 One possible major long-term biomass fuel supply option is expanded use of agricultural residues, assuming continuing real price increases of fuelwood. These include coffee husks, cotton, corn and sorghum stalks, coconut husks and shell, bagasse and groundnut residues. The best defined potential source is the rice crop of the Lac

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10/ This surplus exists as long as no major project does not consume it. It was the mission's understanding that a large ferrochrome project was being studied by the Government. If this project were to be implemented, then the concept of surplus hydropower would not remain, and the conclusions given here would have to be substantially altered. However, in the absence of any definite decision, the mission assumed that the ferrochromium project would not be in operation in the near future.

Aloatra region, which yields annually 36,000 tonnes of rice husks and 110,000 tonnes of rice straw. Although it may be 15 years before the market price would justify transporting raw rice husk briquettes to Antananarivo, carbonized briquettes might be competitive in about 5 years. The costs of the rice crop residue collection and the environmental economics of rice straw utilization should be defined in the Lac Aloatra study proposed in para. (2.24(b)).

Antananarivo Household Cooking Fuels: Supply and Demand

2.21 The data provided in Table 2.3 indicate that the focus of the national woodfuels problem is in the hinterland of Antananarivo where the process of deforestation has been noticeable for decades and where urbanization has been rapid. Annex 3 compares the projected demand for household fuels in the Farintany with the mission estimates of sustainable supply from the existing woodfuels plantation and from the remaining accessible forest cover, which is both in the Faritany of Antananarivo and in the Toamasina Faritany, adding to the supply side the present consumption and simple projections for cooking of electricity, LPG, kerosene and trees, agricultural residues and other combustible refuse scavenged in and around the city. The "supply gap" is shown to be already large and growing. Even allowing for a 1% p.a. decrease in the per capita demand for cooking fuels based on increasing real prices in the Antananarivo marketplace, the estimated deficit of demand over sustainable supply plus the present level of modern fuel consumption grows from 1.2 million twe in 1983 to 2.2 million twe in 1995.

Recommendations

2.22 In the light of the preceding review of the options for improving the fuelwood demand/supply situation, the mission makes the following recommendations for action (in order of priority under each heading):

Top Priority Actions

(a) Project Measures

(i) Carbonizing of Haut Mangoro Pine Smallwood, Thinnings, and Sawmill Waste: detailed design of an overall lump charcoal production investment program including pilot small-holder or semi-centralised based carbonization systems for the uses of each residue; development of detailed resource assessment and carbonizing schedule; credit and other incentives for entrepreneurs; institutional reorganization; and facilitating infrastructure development and detailed project design.

(ii) Rural Afforestation: programs similar to the "micro-boisement" program of the Government and those recommended by the Bank as part of the proposed Forestry III project should be implemented in order to gain early practical experience in rural afforestation. In the context of energy supply, specification of precise quantitative needs by location; and review and design of extension service facilities, infrastructure requirements, technical packages, required incentives and manpower training and development programs.

(iii) Cooking Electrification: review of detailed costs of strengthening and expanding the electricity distribution networks to cater for more electric cooking, including tariff incentives, appliance provision and brief analysis of SRMC and LRMC under a simplified system expansion scenario (in parallel with studies on power efficiency and means of economically utilising surplus hydropower in the main inter-connected power system).

(iv) Expanded Use of Kerosene for Cooking: macroeconomic and petroleum subsector review to determine fiscal and logistical constraints to expanding kerosene supplies, from the present refinery and by imports, and subject to results of these reviews, encouragement of use of improved kerosene stoves, e.g., by reducing duties on imported stoves or encouraging local production of improved kerosene stoves.

(v) Rice Husk Briquette Production: feasibility and design study, followed by early commercial-scale demonstration of rice husk briquette plant in the Antananarivo area, including monitoring and evaluation of performance, consumer acceptance trials of raw and carbonized briquettes, and development of large scale investment program for rice industry.

(b) Technical Assistance and Incentive Schemes

(i) Charcoal-Maker Training and Incentive Schemes: provide expertise for demonstrating simple measures for upgrading traditional earthen kilns through training and extension programs ultimately reaching 2,000 charcoal-makers a year, demonstrating and transferring new techniques and providing credit or grant assistance to motivate required change.

(ii) Forest and Tree Resource Inventory: to lay the groundwork for planning long-term programs of afforestation in the vicinity of each major demand center, DEF should extend its proposed inventory of the forest and tree cover, and potential forest land, in the hinterland of six major urban centers to all significant fuelwood demand centers, and should ensure that the inventory provides total standing biomass by class. As a first step, a brief inventory design study should be made to review existing maps and data, and based on the present mapping program, to cost the required inventory program, including staff training and equipment.

(iii) Forestry Institution Building: review of the organization, management, training needs and equipment needs of the forestry departments of DEF (para. 2.26).

(iv) Sawmill Waste Recovery: an inventory should be made of sawmills and their waste production within reasonable transport access of major urban markets, and a fully commercial program of recovery devised starting with the carbonisation of slab wastes and leading to initially small-scale sawdust and shavings briquetting.

High Priority Actions

(a) Coppice Management: mounting trials and designing extension programs aimed at increasing productivity of existing eucalyptus plantations through improved coppice harvesting and coppice management techniques.

(b) Demand Analyses and Cooking Efficiency Programs: undertake detailed household energy surveys to specify the level and pattern of fuel cooking practices, together with household trials of improved fuelwood, charcoal, kerosene and electric stoves to test consumer acceptance in each socio-cultural setting. 11/

(c) Fuelwood Plantation Program Design: establish the economic and financial viability of peri-urban fuelwood plantations and where justified, specify precise quantitative needs and relative economic merits of fuelwood plantations vis-a-vis other household cooking fuel options by major demand center, and review and design institutional arrangements, interfaces with the private sector, technical options, financing options and overall implementation schedules and investment programs.

(d) With the object of exploiting underutilized forest resources, an early evaluation should be made of the most common logging practices in the lumber industry and the forest types concerned so as to specify:

11/ Trials of improved fuelwood stoves should be coordinated with the ongoing efforts of the Ministry of Scientific Research and Technology for Development in that area.

(i) the actual residues and cull volumes by class for each major forest type for forests in the hinterland of the major urban markets;

(ii) the marginal economic and the financial cost of retrieving as charcoal or firewood each class of fuelwood identified;

(iii) a profile of the logistics for future logging and woodfuels recovery operations for each of the forests concerned as well as the additional capital outlay required to broaden the scope of logging to include charcoal production;

(iv) the institutional arrangements within Government and between Government and the private sector which appear optimal to facilitate the maximum economic level of woodfuel and timber production from State forests;

(v) the overall economic costs and benefits of improved forest management including the expected higher yield and shorter rotation for commercial timber species; and

(vi) an investment and implementation schedule for the required policies, commercial arrangements, infrastructure development and retrieval of the timber and woodfuels concerned for each major demand center.

Lower Priority Actions

(a) A review should be made of the prospects for workable arrangements, including appropriate incentives for local residents or leasers to reforest and protect for sustained fuelwood production the swamp land in the urban area of Antananarivo and other similarly productive urban areas. This will require an inventory of suitable inter-urban and peri-urban land for strip planting, roadside planting or the establishment of small woodlots.

(b) Energy Supply to Agro-Industrial Complexes: initiate an integrated planning study for stabilizing and reducing the cost of supplying energy to the Lac Aloatra region, the main "rice bowl" of the nation, where the impact of deforestation is particularly severe and the cost of mechanical and electrical power is high (see Annex 11 for draft Terms of Reference).

Investment Program

2.23 The mission has made a provisional estimate of the 1986-1995 investment program needed for the studies, technical assistance and projects recommended above. The program is set out at Annex 12 and summarized in Table 2.5. The total requirement over the ten year period is US$60 million. About 53% is for energy forestry, comprising US$21.7 million for 14,000 ha of large-scale fuelwood plantations, US$8.8 million for 27,000 ha of rural afforestation and about US$1.2 million for improved coppice management. Technical assistance requirements are about US$7 million, including a vital component of about US$3.0 million to define pre-investment and planning studies required to formulate the investment program.

Table 2.5: INVESTMENT PROGRAM FOR ENHANCING FUELWOOD SUPPLY AND RESTRAINING DEMAND, 1986-1995 (US$ '000)

	1986	1987-90	1991-95	Total	
	(US$'000)			(US$'000)	(% total)
Forestry	900	12,325	18,575	31,800	52.9
Carbonisation	1,119	956	3,390	5,465	9.1
Rice Husk Briqueting	--	232	744	976	1.6
Electrification	--	1,388	12,409	13,797	22.9
Technical Assistance and Studies	1,730	4,850	500	7,080	11.8
Manpower Training	130	400	500	1,030	1.7
Total	3,879	20,151	36,118	60,148	100.0

Source: Mission estimates.

Organization of Forestry Subsector

2.24 The management and development of the national forests are the responsibility of the Directorate of Fisheries and Forests (DEF) of the Ministry of Livestock, Fisheries and Forests (MPAEF). Within DEF the Service for the Promotion of Forest Products, organized into five divisions, is responsible for forest resources inventory, management, exploitation and reforestation; the Service for Forest Production Studies is responsible for project studies and monitoring. The other main institution in the sector is a parastatal agency, Fanamalanga, which was set up by the Government in the 1960s to develop new plantations to supply the raw material for export to the pulp and paper industry. It has a highly skilled and enthusiastic staff and management and has proved itself a competent plantation development institution.

2.25 The production and marketing of firewood and charcoal form a sizeable national woodfuels business, involving many thousands of producers and traders. Firewood sources range from small copses to vast interconnected stands for which ownership or user rights are not immediately obvious, though interlocking "smallholdings" and leaseholds of several hectares are reported to be typical. Exploitation is by entrepreneurs, who negotiate a fee for the rights to harvest a mature fuelwood lot, or by the owners themselves. Transportation is commonly by oxen and cart or truck over distances up to 50 km though greater distances have been reported. Firewood is delivered both in bulk and pre-packaged in parcels down to 0.5 kg. There are merchants who deal exclusively in firewood and vendors who sell small bundles of kindling along with other goods. The firewood trade is clearly a substantial business which is both competitive and professionally administered and is usually organized independently of the charcoal trade.

2.26 Charcoal production is a thriving industry dominated by small entrepreneurs, mostly farmers but also others who negotiate for the wood resource, organize teams of charcoal makers, and arrange for sale at the roadside to wholesalers or organize their own transportation to wholesalers depots in the urban market place. The typical charcoal supply system, or "filiere", is depicted at Annex 13. The business is efficiently organized and highly competitive. Nevertheless the traditional method of charcoal production is wasteful and transport costs are escalating because of deforestation and deterioration of the transport infrastructure.

2.27 The main institutional problems in the forestry subsector, which are closely linked to the manpower and training issues (para. 2.31), are:

(a) lack of effective planning capability, in relation both to strategic planning for forest management and development and to the fuelwood and charcoal markets which constitute the main outlets for forest products;

(b) lack of an adequate data base for planning, as evidenced in the absence of standing biomass resource inventories and hard consumption data by region. This problem is compounded by shortages of modern office equipment, which cause serious delays in data processing; the analysis of important research data in DEF, for example, is about 18 months behind for lack of minicomputers;

(c) weakness in plantation development and management expertise. This is partly due to the loss of experienced key staff to the parastatal organization, Fanamalanga, to the CENRADERU (National Center for Applied Research in Rural Development) and elsewhere; and

(d) as a result of these institutional weaknesses, there have been misconceived policies or programs, such as the focussing of charcoal experimental work on fixed kilns instead of mobile conversion techniques, and the failure to consider the scope for increasing fuelwood supplies by better forest management, or the conservation potential of improved charcoal and wood stoves.

2.28 Shortage of vehicles and their poor condition, reflecting lack of spare parts, coupled with the appalling state of the road network, severely limit the ability of DEF's staff to carry out essential field work. The deficiencies of the telephone system and lack of radio facilities are a further serious handicap to communication between the central office and the provincial and field offices.

Manpower and Training

2.29 The most serious manpower problems in the energy sector seem to be in the forestry service. DEF's approved budget for 1984 included provision for 100 professional foresters and 600 forestry technicians, but the actual numbers employed at the time of the Bank mission were only 61 foresters and 463 technicians. The shortage of foresters is said to be partly due to relative lack of interest in forestry as a profession in recent years. If it continues, it will have serious implications for the future of the forestry program. The shortage of technicians ("adjoints technique" and "agents technique") is due to the fact that eight "lycées agricoles", which used to train these technicians, have not been functioning for over 10 years. As a result, DEF has not been able to replace technicians leaving its service on retirement or for other reasons.

2.30 Until recently MPAEF had no formal training program for its staff, and training was largely on the job. Some professional staff were sent for training in the past to the French forestry school at Nancy, but the severe foreign exchange shortage limits this possibility. MPAEF now has a training budget but its training plans give low priority to technical, including forestry, staff, the main emphasis being on training in organization, management and planning. This underlines the importance of making specific provision for training needs in forestry projects.

2.31 The main training problem is the non-functioning of the "lycées agricoles", the only source of formal training for forestry technicians. Their reactivation is an urgent necessity if DEF is to have sufficient qualified technicians for its forestry programs, given that one-third of the existing technicians are due to retire in the next 5 to 10 years.

Other Renewable Energy Sources

2.32 This section deals with renewable energy issues other than those which may serve the household cooking fuel market. Biomass fuels examined here have potential to serve industrial, transport or primary power generation fuel markets. In addition to biomass fuels the mission recommends the commercial potential of small scale hydropower, solar, wind and geothermal energy sources in Madagascar.

Biomass Other Than Wood

2.33 The potential use of agricultural residues as direct substitutes for fuelwood has already been reviewed (para 2.19). Two of these resources, in the form of rice residues (husks and straw) and sugar cane bagasse, are produced in sufficient quantities to generate electricity on a commercial scale or to provide a source of fuel for industrial heat and steam raising outside of their own industries.

2.34 Rice Residues. Use of briquetted rice residues for household or industrial fuel or for electricity generation may not be mutually exclusive, given the large size of the resource. As shown in Annex 14, the 36,000 tonnes/year of rice husk produced in the Lac Aloatra rice basin would generate a surplus over the rice mills' power requirements of nearly 22 GWh/year at a full cost of FMG 28/kWh, which compares with FMG 50-60/kWh for the fuel cost alone of diesel power generation. The proposed Lac Aloatra planning study (para. 2.24(b)) would include an assessment of the feasibility of using rice husks and rice straw for electricity generation, as the basis for regional electrification.

2.35 Bagasse. The estimated current national bagasse surplus is 29,000-42,000 oven dry tonnes/year (Annex 15). If the appropriate boilers were installed, this would permit the production of 19-28 GWh/year for local public supply networks, in substitution for diesel power generation, saving 4,800-7,000 toe/year in diesel oil. As shown in Annex 15, a case study by the mission suggests that the prospects look particularly promising in Nosy Be, with estimated full costs of FMG31/kWh (USc5/kWh) for bagasse-fuelled electricity compared with at least FMG43/kWh for the fuel cost alone of diesel generation. Nationwide the estimated total bagasse potential of 19-28 GWh probably exceeds the public demand in the areas which could be served, but not all the potential need be exploited immediately. Furthermore, in the longer term, by radically changing heat and steam management and production systems in line with recently proven innovations, and by recovering cane field husk and cane tops the surplus biomass fuel production capacity of the national sugar industry could reach 260,000 odt/y. The French Caisse Centrale de Coopération Economique (CCCE) is financing a general study of the sugar industry scheduled for spring 1985, which will include an energy specialist to assess the actual potential for surplus bagasse electricity generation. The Bank should monitor this study, and follow up, if necessary.

2.36 Ethanol Fuel. Another by-product of the sugar industry, molasses, is a potential source of ethanol, a substitute for gasoline. The molasses is at present exported as a feedstock, but the Government plans to use part for an ethanol plant at Ambilobe, scheduled for completion in 1986. The mission's analysis of this project considered the use of ethanol only for fuel purposes feeding into the regional market and then the east coast and Antananarivo markets after blending at the Toamasina refinery (Annex 16). The results indicate that even the variable costs of production exceed the equivalent landed cost of gasoline by at least USc9/liter, and the need for additional investment to complete and commission the plant would increase the avoidable losses per liter. It is unlikely that any other form of ethanol production for fuel use would be economic, in light of expected petroleum prices and the location of alternative ethanol plants in Madagascar. A study completed recently by a French consulting firm, however, suggests that there are sufficient higher value, industrial markets for ethanol to ensure the economic viability of a project to produce it. The Ambilobe project may therefore be attractive for the industrial use of ethanol.

2.37 Biogas from Animal Residues. The large population of zebu cattle (over 8 million head) and of pigs and poultry provides a large potential energy source in the form of animal residues amounting, according to one estimate, 12/ to about 2 million toe in 1977. Consequently, biogas production has been investigated by various agencies, and two commercial-scale digesters are operating in the vicinty of Antananarivo, using both continuous and batch digester designs. However, an economic analysis of an experimental digester, for which operating data are available, shows that biogas production is uneconomic, even if the technical efficiency were increased from its actual level of 0.25 m^3 of biogas per m^3 of digester volume per day to 1 m^3 (Annex 17). Except possibly for communal digesters in remote centers, where the benefits of waste treatment and sanitation may justify construction, there is little economic benefit in pursuing biogas as an energy source, especially in comparison with the needs and benefits of rural afforestation.

Small-Scale Hydropower

2.38 Although several resource inventory and detailed design studies of small-scale hydropower have been conducted in recent years (Annex 19), there has not been any significant development of this resource, although a sample analysis suggests it may be competitive with diesel generation in suitable circumstances (Annex 19). This reflects institutional, financial and economic weaknesses in the approach to hydropower development. Firstly, responsibility has been diffused, with more than one agency of government taking responsibility for some part of the development cycle. Secondly, insufficient financial resources have been devoted to small hydropower development, even when it is part of the least-cost solution, while no attempt has been made to encourage private sector involvement. Thirdly, the resource work has lacked a sharp market focus and has paid insufficient attention to the least-cost means of serving the identified end uses for electricity. If these weaknesses can be overcome, the interest exists at the local level in developing the

12/ "Document National", July 1981, submitted by the Malagasy Government to the UN Conference on New and Renewable Energy Sources, Nairobi, August 1981.

potential, as evidenced by the fact that, despite the severe constraints, some communities have succeeded in developing their own hydropower resources. 13/ Wherever private sector interest in hydropower development exists, especially at community level and for micro or macro hydropower, the GOM should encourage the use of private rather than public capital and human resources for this purpose, including arrangements for buying surplus production for distribution by JIRAMA where economic.

Hydrology

2.39 Accurate long-term hydrological records are essential wherever multi-million dollar investments in hydropower are contemplated. Given the huge resources potential in Madagascar, a systematic market-oriented program of stream gauging is required. Presently available records of stream flow are of highly variable quality and extremely limited in quantity. Acknowledging the long lead time for the collection of useful hydrological records and the need for sustained high quality in data management and analysis, the mission recommends the establishment of a central agency for hydrological data collection and interpretation. This independent agency would establish its program of steam gauging on the basis of advice from JIRAMA and other agencies which had made preliminary assessments of the commercial potential of specific resources for power irrigation and so on, leading to a ranking of sites for more detailed recording.

Solar, Wind and Geothermal Energy

Solar Energy

2.40 While there are certain to be applications for photovoltaic power systems for lighting, communications systems, and small refrigerators for preserving medicines in remote health centers, they do not represent significant markets in the short-term and should not preoccupy government agencies. Photovoltaic lighting and small DC appliance kits (radios, tape recorders, rechargeable torches, etc.) should be economic for households wherever the retail price of kerosene exceeds US¢50/liter and kerosene lamps are used regularly. Solar water heating for hotels, hospitals and homes using electric water heating offers more potential. The Centre de Développement Industriel of the Commission of the European Communities has defined the potential market for solar collectors in Madagascar as 1500 m^2 for hotels, 8500 m^2 for health centers and 750 m^2/y for domestic solar water heaters. The corresponding annual fuel

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13/ For example, JIRAFI, a cooperative of local communities, has developed its own 107 kW hydropower station in Fianarantsoa province.

displacement of about 500 toe/y in the short-term is not significant in national terms. However, the household solar collector market is large enough to be profitable for small private sector traders importing partly assembled collector units from reputable international suppliers. An illustrative economic analysis (Annex 20) suggests that private sector companies are unlikely to invest in industrial-scale solar water heating systems, but the investment may be acceptable to Government-owned enterprises which should find payback periods of greater than five but less than ten years attractive.

Wind Power Generation

2.41 Madagascar has abundant, though unevenly distributed, wind energy resources. An analysis by the mission (Annex 21), based on data of the National Meteorological Service, shows that wind power can become competitive at a delivered economic cost above FMG 270/liter for diesel oil. This compares with a current (May 1984) market price of diesel in Antananarivo of FMG 186/liter, and the corresponding economic cost (c.i.f. price) of FMG 121/liter (para. 6.3). A small research team, with Swiss technical assistance, has been working on wind electric systems at the Ecole Polytechnique in Antsiranana, but main hardware components will have to be imported fully assembled for the foreseeable future. Local work should continue along present lines, followed by one or two small pilot projects, but the mission does not regard the program as of high priority. However, the wind power option should be studied every time local electrification programs are assessed in areas where the average assessed wind speed exceeds 5 m/s.

Geothermal Energy

2.42 An initial appraisal of geothermal resources in 1979 identified eight sites with temperatures high enough (over 150°C) for power generation and industrial steam supply (Antsirabe, Itasy, Miandrivaka, Ambilobe, Ambanja, Andapa Doany, Nosy Be and Morondava). More detailed surveys are under way or have generated data that are now being processed. However, at least three factors unfavorable to development are the relatively great depth of the resource and hence significant costs of pumping; the need for a local or regional power/energy demand at each site of at least 20 MW in order to justify the large initial investment; and the existence of many competing energy resources, especially hydropower, which are reasonably accessible and probably cheaper. For these reasons, the mission believes that there is little justification for actively pursuing geothermal energy development except in regions with limited hydropower potential and prospects for development of large, economically viable enclave industries (e.g., mining).

Recommendations on Other Renewable Energy Sources

Top Priority Actions

(a) A review should be made of all previous assessments of the small-scale hydropower potential in order to determine which, if any, of the identified sites can economically displace existing diesel power generation, public or private; and

(b) If this study demonstrates a significant economic potential for small-scale hydropower development, it should be followed immediately by a second prefeasibility phase to:

(i) define the institutional, legal and financial framework for development in both the public and private sectors;

(ii) formulate an investment program for the public sector, based on design and costing studies for several minihydro projects of demonstrated economic viability; and

(iii) estimate the finances required to encourage private sector participation in development; and

(c) A central agency should be established for hydrological data collection and interpretation.

High Priority Actions

(a) The CCCE study of the sugar industry should be monitored and followed up, if necessary, by further pre-investment work on the potential for a bagasse-fuelled electricity supply. Where a power market does not exist, or is too small to absorb the bagasse surplus, production of briquetted fuel for industry and households should be evaluated.

Lower Priority Actions

(a) The Government should encourage private sector application of photovoltaic power systems by allowing their importation without duty or taxes wherever diesel-fuelled electricity generation would be the source of electric water heating (e.g., in large settlements for enclave industries, such as Fanamalanga and SOMALAC); and

(b) Wind energy research should concentrate on site specific design, regulation, minimum maintenance programs and service training. One or two pilot projects up to, say, 100 kW, could logically follow, after economic and market analysis, in close coordination with JIRAMA, although operated as enclave projects under separate management.

Technical Assistance

2.43 The priority areas for technical assistance in relation to renewable energy sources are as follows (the costs given are from Annex 12):

Resource Development

(a) Resource inventory work, covering (i) inventory of the forest and tree cover, and potential forest land in the area of all major fuelwood demand centers (para. 2.22(b), (ii)) evaluation of logging practices in the lumber industry to determine actual residues (para. 2.23(d)), and (iii) inventory of sawmills and their waste production (para. 2.2(b)(iv)). The estimated cost is US$2.5 million over the period 1986-90.

(b) Detailed surveys of household cooking fuel consumption in each major demand center at an estimated cost of US$0.32 million over the period 1986-88 (para. 2.23(b)).

(c) Cooking efficiency programs to test consumer response to improved stoves at an estimated cost of US$2.53 million over the period 1986-90 (para. 2.23(b)).

(d) Energy planning study for Lac Aloatra region at an estimated cost of US$0.53 million over the period 1986-87 (para. 2.24(b)).

(e) Feasibility and design study to refine the costs and benefits of rice husk briquetting in the Antananarivo area at an estimated cost of US$50,000 in 1986-87 (para. 2.22(a)(v)).

(f) Study to determine the feasibility, and costs, of increasing the use of electricity for household cooking at an estimated cost of US$50,000 in 1986 (para. 2.22(a)(iii)).

Institution Building

(a) Review of the organization, management, training needs and equipment needs of the forestry departments of DEF (para. 2.26). It is understood that FAO is already considering technical assistance for this purpose, but IDA should help, if necessary, under the proposed third forestry project.

Training

(a) Training in improved charcoal-making techniques, including paid certificated courses for charcoal-makers at an estimated cost of US$1.1 million over the period 1986-95 (para. 2.22(b)(i)).

III. DEVELOPMENT OF SOLID FOSSIL FUELS

Exploration and Reserves

3.1 Madagascar has long been known to contain reserves of coal and lignite and more recently indications of peat resources have been reported. These resources have not been exploited commercially because of their relative remoteness from markets and the lack of industrial demand. Interest in the coal resources has revived in the last ten years with the increase in oil prices.

Coal

3.2 Bituminous coal outcrops in south-west Madagascar along the south-east edge of the Morondava sedimentary basin, which runs the length of Madagascar and extends westward some 100-200 km offshore. Exploration since the early part of the century has led to the identification of seven areas where coal is known or its presence inferred (Annex 24). They include five principal coalfields, all in the Sakoa basin, about 900 km from Antananarivo and 100-200 km from the sea (see map IBRD 19743). A summary of the stratigraphy is attached (Annex 25). No systematic evaluation of the coal resources has been made but estimates for the whole Sakoa basin are as high as 1,000 million tonnes, which may be slightly higher than the available data justify. Of the five main coalfields, the Sakoa field contains the most important known resource in Madagascar of moderate ash, medium volatile steam coal, with estimated mineable reserves of 173 million tonnes. According to the consulting firm Saarberg Interplan, of these reserves, an estimated 82 million tonnes would be recoverable by underground methods. In its analysis of the Sakoa deposit, BP concluded that 23 million tonnes could be recovered by open-pit methods to a maximum 10:1 volume to volume (v/v) ratio in areas already explored in detail (to a maximum of 5:1 v/v ratio this figure falls to 250,000 tonnes). The run-of-mine coal produced at Sakoa in the past (para. 3.5) had 16.4% ash, 25.4% volatile matter and 0.8% sulphur on an air-dried basis.

Lignite

3.3 The principal lignite resources occur in the Antsirabe region of the central highlands. The only deposit of potential interest is Seam 3 at Antanifotsy. The U.S. Bureau of Mines (1961) estimated the total reserves in this seam as about 32 million tonnes, including 18 million tonnes of measured reserves (Annex 27). A more recent UNDP estimate (1970), based on more extensive exploration, puts the total at some 54 million tonnes, including 11 million tonnes of proven reserves. The ash content is 15-20%, sulphur 2.5%, calorific value 1900-3000 kcal/kg and moisture over 45% (the heat value reportedly rose to 4,000 kcal/kg after drying to less than 20% moisture). Although not of prime quality, the deposit would have economic potential if it were easily mineable.

This does not appear to be the case, since there are no reserves that could be recovered by open-pit methods, and the seam is reported to be faulted, lenticular and undulating, and to have "much water". It is concluded that development would not be economically justified in the foreseeable future. Several lignite occurrences investigated in western Madagascar likewise offer no economic potential for development.

Peat

3.4 The peat resources have not been investigated. Some reports speak of occurrences of about two meters or more in thickness, but the basis for this is unknown, as is the location of the peat. Deposits visited near Antananarivo, used as fuel for brick kilns, were all very lenticular and less than one meter thick. Nevertheless, a systematic inventory of peat resources should be undertaken.

Past Development

Coal

3.5 Past development activity has focussed primarily on the Sakca coalfield. A private mining company ("Société des Charbonnages de Sakoa") was founded in 1931. The first production was at a small pilot mine in 1941, serviced by an 85 km railway line from Soalara on the coast to Vohitsara. This mine was operated intermittently until 1972, producing 53,000 tonnes of coal. There has been no further development, although there have been several mine feasibility studies, notably by Charbonnages de France/BRGM in 1964, KOPEX of Poland in 1978 and Saarberg-Interplan of West Germany in 1979. Utah International and Amax Inc. of the USA have made proposals to the Government to do work in the last ten years, although no physical work appears to have been undertaken.

Lignite

3.6 Some lignite was mined in the period 1947-49, when 570 tonnes were produced for use by the railway. There is no current exploitation.

Peat

3.7 Peat is being used increasingly as fuel for artisanal brick-works in place of fuelwood. No estimate of consumption is available.

Market for Coal

Past Trends

3.8 The cement industry, in the shape of the plant operated by Cimenterie de Amboanio (CIMA) near Mahajanga in north-west Madagascar, provides the only market for coal at present. As shown in Annex 27, annual consumption from 1968-80 was mostly in the vicinity of 20,000 tonnes, but has since fallen to 12,000 tonnes with the decline in cement production to about 50% of the plant's capacity. 14/ All the coal is imported, currently from Maputo in Mozambique.

Future Demand

3.9 There appears to be little scope for establishing a domestic market for coal outside of the cement industry. While a detailed assessment of the prospects for conversion of industry to coal as a primary fuel was not made, it is clear that the opportunities are limited not only by the small industrial sector but also by the lack of infrastructure to receive, transport and deliver coal at competitive prices. Similarly, the option of coal based power generation at Toliara, or at the Sakoa mine head for transmission to nearby isolated regional centers, was likewise not considered by the mission, given the relatively small quantities of diesel based power that could be replaced and the corresponding high unit cost involved. A maximum domestic market other than for cement has been assumed of 10,000 tonnes per year by 1995.

3.10 The future internal demand for coal will continue to depend essentially therefore on the trend in demand for cement. Cement consumption has varied from 11 kg to 17 kg per capita in the last 10 years (Annex 29). On current economic prospects it is unlikely to exceed 20 kg by 1990, or 25 kg by 2000. Assuming population grows at 2% annually, this would imply the scenario shown in Annex 29, with cement consumption rising to 226,000 tonnes in 1990 and 280,000 tonnes in 2000, of which 160,000 tonnes and 255,000 tonnes respectively would be met by domestic cement plants. The corresponding coal requirements are estimated at about 33,000 tonnes in 1990 rising to 50,000 tonnes in 2000 (Annex 29).

3.11 The resulting projection of total domestic demand for coal is some 43,000 tonnes in 1990, rising to 60,000 tonnes in 2000 (Annex 30). These are to be regarded as maximum figures, and actual demand could well fall short. Potential demand for indigenous coal will be much lower (26,000 tonnes in 1990, 40,000 tonnes in 2000), because the cement kilns under construction at Ibitsy (Antsirabe) can use only low volatile coal which must be imported. Furthermore, an on-going supply of about

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14/ The decline in output is due to a lack of spare parts for proper maintenance of the plant, which is very old (1956).

10,000 tonnes per year of lump charcoal from Moromango pines clearing and thinning may be best used in cement production displacing imported coal.

3.12 Prospective demand for Sakoa coal during the 1990s might increase substantially, should the envisaged "Cimenterie des Trois Iles" (Madagascar, Mauritius, Seychelles) with a capacity of one million tonnes cement p.a. be found to be economically feasible, which seems doubtful at this time. A feasibility study of this project has been proposed for financing by FED.

Coal Imports

3.13 The cement industry purchases its coal through an agent in France. The costs since 1977 are summarized in Annex 31. The average price paid in 1983 was US$96.34 per tonne landed Mahajanga. The main component of US$50.50 per tonne f.o.b. Maputo is probably at least US$10 more than would have been expected for coal of the quality supplied (moisture 8%, volatile content 23%, ash 19%, sulphur 1.2% and calorific value 6210 kcal/kg). The shipping charge of US$27.85 per tonne may also seem high, but it probably includes significant demurrage charges resulting from the use of small barges (less than 100 tonnes capacity) for unloading. Unloading charges were about US$7 per tonne, plus a further US$10 per tonne for losses. The only cost item with significant potential for reduction without changes in infrastructure, unwarranted by the small tonnages, appears to be the f.o.b. price, perhaps by purchasing directly rather than through an agent (although, as for petroleum (para. 5.10), the high price paid may reflect the cement industry's restrictive payment terms resulting from the foreign exchange shortage). 15/

Coal Development Schemes

3.14 There are no plans for lignite or peat development. Present Government hopes for coal development rest on a joint venture agreement recently made with BP (Coal) Limited (BP), a subsidiary of British Petroleum Limited. This gives BP an exclusive option for coal development over most of the prospective area of south-west Madagascar on condition that BP undertakes (a) to carry out at its sole cost exploration and, if warranted, subsequent feasibility work for a major open-pit mine (over three million tonnes per year) to produce coal for export, and (b) to prepare as soon as possible a feasibility study for a small mine to be developed immediately to supply the local domestic market. The

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15/ The price of coal on the international market has come down since 1983. Thus, in 1986, Madagascar's cement industry was paying up to US$75 per tonne landed Mahajanga, as opposed to US$96 in 1983. However, this still reflects a high price f.o.b. Maputo.

Government would have a 50% equity in the large mine and contribute its share of the capital at the development stage.

Large Export Mine

3.15 BP will investigate the whole Sakoa basin area (para. 3.2), focussing primarily on the Imaloto coalfield (Annex 24), in an attempt to locate reserves with a low overburden to coal ratio which could be mined to provide a minimum of three million tonnes per year for export. BP have carried out conceptual studies on the assumption that the required tonnage would be mineable over 20 years at an average stripping ratio of three cubic meters of overburden per tonne of run-of-mine coal, i.e., at a 4.5:1 stripping ratio on a volume to volume basis; that the coal will be available in two or three seams 1.5-4 m thick dipping between 0° and 10°; that the run-of-mine coal will require washing to meet export quality standards; and that yields of clean coal of export quality would be 80-90% of the run-of-mine coal.

3.16 BP's "first broad brush estimates" of costs on these assumptions (in 1984 US$) are US$561 million for capital (including infrastructure) plus operating costs of US$13.60 per sales tonne for a 5 million tonnes per year scheme, or US$867 million plus operating costs of US$13 per tonne for a 10 million tonne scheme. These cost estimates would imply coal costs f.o.b. Toliara, the nearest port, of US$30-40 per tonne, which would probably be internationally competitive. However, the geological assumptions appear over-optimistic. There is no evidence to suggest coal seams of the thickness postulated (Annex 24), and almost the total area possibly underlain by coal measures (about 30 km^2) would have to be mineable at favorable ratios to sustain the high production rates being considered. Moreover, given the depressed state of the international thermal coal market, and the low cost of incremental production in South Africa, Australia and the USA, it is difficult to envisage a market for coal from such a new project before 1995 at the earliest, and it is more likely to be after 2000.

Small Coal Mine

3.17 The critical issue concerns the size of the proposed small mine. BP have undertaken to carry out a feasibility study for a mine producing 50,000-100,000 tonnes per year, which the Government is interested in developing. This would appear to be appropriate, since the projected domestic demand is not expected to exceed 60,000 tonnes before 2000, or even later (para. 3.11). However, the mission's preliminary estimates for such an open-pit mine, based on previous exploratory work at Sakoa, suggest that such a mine is unlikely to be viable for the foreseeable future.

3.18 Consideration had been given to carrying out a feasibility study of a 400,000 tonnes per year mine instead of 50,000-100,000 tonnes. This size mine presupposes that the production in excess of domestic demand could be exported, which is unlikely for several reasons. Firstly, the run-of-mine coal would have to be washed to make it suitable for export; secondly, the overburden to coal ratio would increase for the higher production and the saleable coal per tonne of run-of-mine coal would probably be about 0.75 tonne; and, thirdly, there would be significant infrastructure requirements for transporting the coal from mine to port and handling it at the port. The resulting coal cost f.o.b. Toliara would be well in excess of current (US$35/tonne) and projected costs (US$45 in 1995) 16/ for coal f.o.b. South Africa or Australia. The cost of coal produced from the larger mine would also make it uncompetitive with imported coal for domestic consumption.

Conclusions

3.19 Although Madagascar has extensive resources of bituminous coal potentially suitable for the international thermal coal market, there is little possibility of such development in the foreseeable future. Market conditions are poor for potential new producers, with stagnant prices and little prospect of significant real price increases over the next ten years. To develop Madagascar's coal resources on an export scale would require very large infrastructure investments (rail, port, etc.). Moreover, the probability of locating reserves recoverable at competitive prices is low, since all present indications are that the bulk of the resources would have to be developed by relatively high-cost underground mining methods.

3.20 There are no prospects for the development of lignite resources. The mission supports the Government's position that no further investigation of these resources is warranted at the present time.

3.21 Although the peat reserves have not been investigated, they may occur at many locations throughout the country, and there is potential for significant discoveries which should be evaluated.

Recommendations

3.22 The mission recommends that:

(a) the Government should encourage further exploration of the coal resources if this can be done at no cost to the Government under a suitable agreement with BP;

(b) no further investigation of lignite resources should be undertaken at present; and

(c) in view of the shortages and rapidly rising prices of fuelwood, an evaluation of the peat resources should be undertaken as soon as possible.

16/ In 1983 US$.

Institutional Issues

3.23 The main institutional issue in the coal subsector concerns the respective responsibilities of MIEM and OMNIS for studies related to the development of coal resources. According to its terms of reference, this is the responsibility of the Mining Projects Division of the Mines and Geology Service of MIEM. Since 1983, however, when OMNIS negotiated a contract with BP for a coal study, OMNIS has effectively taken over this responsibility, although the decree establishing OMNIS says nothing about coal. This arrangement has evidently been mutually agreed between MIEM and OMNIS, partly because of the experience OMNIS already has in negotiating petroleum exploration and development agreements.

Recommendation

3.24 The mission recommends that the respective responsibilities for MIEM and OMNIS for coal exploration and development studies should be clearly defined to avoid duplication of work.

IV. ELECTRIC POWER SUBSECTOR DEVELOPMENT

4.1 This chapter focusses on the past and projected growth of electricity demand and the associated development of the public supply system. Electricity pricing issues are addressed in Chapter VI.

Growth of Demand

Past Trends

4.2 Electricity consumption, as measured by sales to consumers connected to the public electricity supply, rose at 4.4% p.a. on average in the period 1973-83, from 203 GWh to 313 GWh (Table 4.1). Year-to-year growth rates fluctuated widely about the average, with a high of 14% in 1979 and an actual decline of 1% in 1982 (Annex 32). Although there is no close correlation between the growth of electricity consumption and the growth of GDP on a year-to-year basis, the exceptionally large increase in electricity sales in 1979 was mainly due to a 17% growth in industrial electricity consumption, reflecting a 13% increase in industrial output. The subsequent declining growth rate of electricity sales in 1980-82 was likewise associated with sharp declines in industrial output in those years. As shown in Table 4.1 (details at Annexes 32 and 33), the growth rate in the interconnected system, which covers the Antananarivo region, was just over half the rate for the other areas 17/ covering the rest of the country (3.4% against 6.4% p.a.). Figures of maximum demand for the whole country are not available, but for the interconnected zone it rose more rapidly (4.1% p.a.) than sales, from about 30 MW to 45 MW. Consumption per capita for the country as a whole rose from 31 kWh in 1973 to 38 kWh in 1983, one of the lowest in the world.

4.3 The pattern of electricity consumption by consumer category has shown relatively little change (Table 4.2). After rising from 51% of total sales in 1973 to 55% in 1976, the share of the industrial sector subsequently declined to under 53%. The most important industrial consumers are food processing, tobacco, textiles, paper and leather, which accounted for nearly [illegible]0% of industrial consumption in 1983. Residential sales rose from 26% to nearly 28% over the period, reflecting their somewhat faster growth rate compared with industrial sales. Nevertheless, consumption per residential consumer fell from 738 kWh to 609 kWh in 1977, recovering only partially to 688 kWh in 1983. The decline reflects falling living standards, coupled with a shortage of bulbs (most of the domestic use of electricity is for lighting) and appliances. The biggest relative change was in the smallest category, public lighting, which fell

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17/ "External zones" plus "isolated centers" (see para 4.6).

from over 4% to less than 2% as a result of a decline in consumption from 8.7 to 5.4 GWh.

Projected Demand

4.4 JIRAMA has made a detailed projection of electricity consumption by area to 2000. This is given at Annex 34, and consolidated presentations for the interconnected system and the whole country at Annexes 35 and 36. As shown in Table 4.3, which presents a summary for the period 1983-95, the projection implies that total sales will grow at 7.1% p.a. to 1985, 5.3% p.a. in 1985-90 and 3.7% p.a. in 1990-95, reaching 556 GWh in 1995 compared with 313 GWh in 1983. Achievement of the sales projections to 1990 would require a sharp reversal of the 1979-83 trend, when sales grew at only 2.9% p.a. As Table 4.3 makes clear, the relatively high growth rates of total sales to 1990 are entirely attributable to the high projections for the interconnected system, since sales in the "external zones" are projected to grow much more slowly than in 1979-83. 18/ This suggests the need for a critical review of the "interconnected system" projections to 1990, which imply growth rates of over 7% p.a. for both sales and maximum demand in this period, although it is assumed that there will be no major new industrial loads. In view of prevailing economic conditions, the mission has assumed a scenario entailing lower rates of growth in power demand for the country as a whole, 3.5% p.a. in the period 1985-1995 (Annex 41) as opposed to 5% p.a. projected by JIRAMA.

4.5 Given the relatively low level of current and projected electricity demand, the emergence of any significant new load would have a substantial impact. It is important, therefore, that the timing of any major new electricity-consuming project, such as the ferrochrome, paper pulp, steel works and additional cement plants which have been mooted, should be properly phased in with any additional power facilities which may be needed to ensure that electricity requirements can be met. A new cement plant at Amboanio in the Mahajanga region (one of the external zones), for example, such as has been proposed, would add another 50 GWh to the projected 1990 consumption in the region of some 72 GWh (Annex 34).

18/ It should be noted that these projections assume that Toamasina (one of the present external zones) will be connected to the interconnected system in 1988. This assumption contributes 1.5% of the 7.3% projected yearly increase in sales to 1990 in the interconnected system. Given the current situation in the power subsector, it does not seem likely that this connection will have taken place in 1988.

Table 4.1: ELECTRICITY CONSUMPTION, 1973-1983

	1973	1976	1979	1980	1981	1982	1983	Growth Rate 1973-76	1976-79	1979-83	1973-83
								--- (percent p.a.) ---			
Interconnected System											
Sales, GWh	138.2	146.6	172.6	180.0	182.0	180.2	192.3	2.0	5.6	2.7	3.4
Maximum Demand, MW	30.2	32.5	38.0	40.0	41.5	44.6	45.3	2.5	5.4	3.6	4.1
Other Areas											
Sales, GWh	65.1	82.4	106.4	115.6	120.8	119.8	120.6	8.2	8.9	3.2	6.4
Total Sales, GWh	203.3	229.0	279.0	295.6	302.8	300.0	312.9	4.0	6.8	2.9	4.4

Source: JIRAMA.

Table 4.2: ELECTRICITY CONSUMPTION BY CONSUMER CATEGORY, 1973-1983

	1973		1976		1979		1983		Growth Rate a/			
									1973-76	1976-79	1979-83	1973-83
	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)	--- (percent p.a.) ---			
Residential	53.4	26.3	54.9	24.0	68.0	24.4	86.7	27.7	0.9	7.4	6.3	5.0
Industrial	103.8	51.1	126.8	55.4	150.4	53.9	164.4	52.6	6.9	5.9	2.2	4.7
Administration	14.5	7.1	13.8	6.0	17.0	6.1	18.9	6.0	(1.7)	7.2	2.7	2.7
Water Pumping	13.1	6.4	14.2	6.2	20.5	7.3	22.7	7.3	2.7	9.6	2.6	5.6
Public Lighting	8.7	4.3	9.0	3.9	10.1	3.6	5.4	1.7	1.2	3.9	(14.5)	(4.6)
Other	9.8	4.8	10.3	4.5	13.0	4.7	14.8	4.7	1.7	8.1	3.3	4.2
Total	203.3	100	229.0	100	279.0	100	312.9	100	4.0	6.8	2.9	4.4

a/ Figures in parentheses are rates of decline.

Source: JIRAMA.

Table 4.3: PROJECTED ELECTRICITY DEMAND, 1985-1995

	1983 (actual)	1985	1990	1995	Growth Rate 1983-85	1985-90	1990-95	1983-95
					— (percent p.a.) —			
Interconnected Zone a/								
Sales, GWh	192.3	228.1	316.9	378.0	8.9	6.8	3.6	5.8
Maximum Demand, MW	45.3	52.3	74.3	85.5	7.4	7.3	2.8	5.4
Isolated Centers								
Sales, GWh	1.5	1.9	3.2	5.0	12.0	11.0	9.3	10.3
External Zones a/								
Sales, GWh	120.6	129.0	144.6	173.0	3.4	2.3	3.7	3.1
Total Sales, GWh	312.9	359.0	464.7	556.0	7.1	5.3	3.7	4.9

a/ Projections assume that Toamasina (one of the present external zones) will be connected to the interconnected system in 1988.

Source: JIRAMA.

Demand Issues and Recommendations

4.6 The main demand-related issues are:

(a) There is a need for close monitoring of the development of demand, particularly in the industrial sector, because of the uncertain timing of major industrial projects and their substantial potential impact on electricity demand. This calls for a strengthening of JIRAMA's load research and forecasting capability, with the emphasis on regular updating of short- and medium-term projections.

(b) The present forecast for the interconnected system is high compared with the recent trend and a new and more detailed demand forecast is both warranted and urgently required. This load forecast should be based on actual consumption and proposed investment plans for existing and proposed major industry and commercial uses through 1990, and on more conventional load forecasting techniques thereafter.

(c) JIRAMA should investigate the possibility of promoting household consumption of electricity, e.g. for cooking, in view of the hydropower surplus and the desirability of restraining the growth of fuelwood consumption. This will entail analyzing: (i) the effect of increased consumption on peak demand; (ii) the cost of strengthening distribution networks and improving household wiring; (iii) the possibilities of promoting the development of a low-cost, high-efficiency electric rice cooker (para. 2.18); and (iv) the innovative tariff structures required.

(d) It is particularly important for JIRAMA to determine the impact on the system energy and capacity balance of the recently revised estimate of the ferrochrome industry load in order to determine the likely timing and scale of new capacity and energy additions, should this industry proceed, and to estimate the true cost of supply to the industry, and hence appropriate tariff levels on a daily and seasonal basis.

Electricity Supply

Existing Facilities

4.7 Total installed generating capacity in the public supply system is 204 MW, comprising 30 hydropower plants totalling 105 MW and over 160 diesel units totalling 99 MW (Annex 37). It is divided into three groups (IBRD Map 18816), as follows:

(a) The interconnected system, which covers Antananarivo and the surrounding area, accounts for about 62% of the capacity, with 92 MW of hydropower and 34 MW of diesel plant. The largest units in the system are the two 29 MW hydropower sets at Andekaleka; the largest diesel unit is 7.5 MW. Main transmission is by 400 km of 138 and 60 kV line.

(b) Eight isolated centers, which are within the area covered by the interconnected system, but are too remote to be connected to it. They have about 2 MW of capacity, all diesel except for two 50 kW hydropower units.

(c) The external zones, i.e., the areas outside the interconnected system, are served by 135 diesel units from 6 to 9000 kW in size, totalling 63 MW, and 12 small hydropower units (40 kW to 2800 kW), totalling 13 MW.

The large number of diesel units of many different types and sizes, and the age of some of the units (over twenty years), give rise to problems in operation and maintenance.

Autogeneration

4.8 Outside the public supply system, there is an estimated 62 MW of thermal capacity, operated by various industries for their own use (Annex 38). In addition, there is an estimated 10 MW of hydropower. Sugar mills account for about 28 MW (available capacity 17 MW) of the thermal capacity in the form of bagasse-fuelled steam stations, which operate only during the crop season to provide process heat and electricity. The rest of these autoproducers' plants are used for standby purposes in areas supplied by JIRAMA, or by a number of small industries in areas where public power supply is not available.

Past Supply Trends

4.9 Supply capability in the interconnected system has been well in excess of maximum demand. As shown in Table 4.4, the margin of firm capacity as a percentage of maximum demand declined during the 1970s, but in 1979 it was still 30% of the demand. It took a big jump with the installation of the two 29 MW units at Andekaleka, rising to 53 MW in 1983, or 116% of the maximum demand in that year. System load factor has shown a tendency to decline, falling from 58% in 1973 to 56% in 1983. It is likely to remain around this level in the absence of any major new industrial concern operating on a continuous basis.

Table 4.4: ELECTRICITY SUPPLY, INTERCONNECTED SYSTEM, 1973-1983

	1973	1976	1979	1983
Installed Capacity, MW	55.4	55.4	55.4	126.9
Firm Capacity, MW a/	49.4	49.4	49.4	97.9
Maximum Demand, MW	30.2	32.5	38.0	45.3
Capacity Margin, MW	19.2	16.9	11.4	52.6
Capacity Margin, %	64	52	30	116
Generation, GWh	153.2	161.6	189.8	221.4
System Load Factor, %	58	57	57	56

a/ Firm capacity is defined here as installed capacity less the biggest single generating unit, which was 6 MW up to 1983, and 29 MW in 1983.
Source: JIRAMA.

4.10 The installation of the Andekaleka hydropower plant has also profoundly affected the pattern of supply. During the 1970s the respective contributions of thermal and hydropower generation to total supply were reversed, the thermal proportion rising from 28% in 1973 to 62% in 1979 (Table 4.5). By 1983 the situation had been reversed once more, the thermal share declining to 31% and the hydro share rising to 69% as Andekaleka came to dominate output in the interconnected system. The percentage of losses in the interconnected system has risen somewhat (from 8% of gross generation in 1979 to 9% in 1983), but these figures still look very low, particularly since they include unspecified amounts of unbilled electricity consumption.

4.11 Oil consumption for electricity generation in the public supply system has also declined as a result of the increasing substitution of hydropower for thermal generation. As shown in Table 4.6, fuel oil usage in thermal stations dropped from about 20,000 toe in 1979 to 12,400 toe in 1983, and gas oil usage from 28,000 toe to 15,700 toe, giving a total saving in oil consumption of 20,000 toe in the later year. As a percentage of total oil demand, consumption for electricity generation rose from 11% in 1978 to 14% in 1981, but then declined to 10% in 1983. As shown in Table 4.6, specific consumption increased somewhat in 1982. This reflects a decrease in the use of the more efficient diesel plants, either because they had been displaced by the Andekaleka hydropower station, or because they were simply not operational.

Table 4.5: PATTERN OF ELECTRICITY SUPPLY, 1973-1983

	1973	1976	1979	1983
Installed Capacity, MW	a/	100.2 (100)	114 (100)	204 (100)
- Thermal	a/	60.7 (61)	72 (63)	99 (49)
- Hydropower	a/	39.5 (39)	42 (37)	105 (51)
Generation, GWh	228.6 (100)	254.6 (200)	312.2 (100)	360.2 (100)
- Thermal	64.9 (28)	82.7 (32)	194.6 (62)	112.3 (31)
- Hydropower	163.7 (72)	171.9 (68)	117.6 (38)	247.9 (69)
Station Supply, GWh	a/	a/	8.6 (3)	14.7 (4)
Losses, GWh b/	a/	a/	24.6 (8)	32.7 (9)

a/ Not available.
b/ Including unbilled consumption.
Source: JIRAMA.

Table 4.6: OIL CONSUMPTION FOR ELECTRICITY GENERATION 1978-1983 ('000 toe)

	1979	1980	1981	1982	1983
Fuel Oil	20.0	21.5	23.6	11.6	12.4
Gas Oil	28.0	24.9	21.6	17.5	15.7
Total	48.0	46.4	45.2	29.1	28.1
Grams/kWh	247	246	247	254	250

Source: JIRAMA.

Projected Supply

4.12 Details of the projected supply to meet the forecast demand (para. 4.4) are given in Annex 35. Table 4.7, which is based on Annex 36, compares projected supply and demand in the interconnected system, on the basis of dry-year generation. It shows that no additions to generating capacity will be needed in the interconnected system through 1995, and probably not until about 1998, despite the fact that required generation is forecast almost to double, from 221 GWh to 435 GWh, by 1995. This is because of the continuing surplus of energy and capacity available at Andekaleka throughout the period. As shown in Table 4.7, the firm energy surplus is still 78 GWh (18% of required generation) in 1995, although the capacity margin is down to 3.5 MW (4% of maximum demand) by that date.

Table 4.7: ELECTRICITY SUPPLY IN INTERCONNECTED SYSTEM
1985-1995

	1983 (Actual)	1985	1990	1995
Interconnected System				
Required Generation, GWh	221.4	262.2	364.7 a/	434.5
Firm Generation, GWh b/	512.6	512.6	512.6	512.6
Firm Energy Surplus, GWh	291.2	250.4	147.9	78.1
Installed Capacity, MW	126.9	118 c/	118	118
Firm Capacity, MW d/	97.9	89	89	89
Maximum Demand, MW	45.3	52.3	74.3	85.5
Capacity Margin, MW	52.6	36.7	14.7	3.5
Capacity Margin, %	116	70	20	4

a/ Toamasina assumed connected to system in 1988. Toamasina demand is included in required generation but, to emphasize existing ICS surplus capacity, installed capacity in Toamasina is not used to increase ICS firm generation or capacity.
b/ Energy available during the driest hydrological year.
c/ Small thermal plants older than 20 years retired.
d/ Firm capacity is defined here as installed capacity less the biggest single generating unit (1 x 29 MW).

Source: JIRAMA.

4.13 As shown in Table 4.8, the respective shares of thermal and hydropower generation in total electricity supply are expected to remain relatively stable over the forecast period at around 30% and 70% respectively. In the interconnected system, however, thermal generation is projected to shrink to negligible proportions by 1995, at which time hydropower will account for over 99% of generation. Outside the interconnected system, the situation is reversed, thermal generation accounting for over 97% of total supply in 1995 compared with 77% in 1983.

4.14 Although the proportion of thermal generation shows little change over the period, its amount is projected to increase from 112 GWh in 1983 to 187 GWh in 1995. As a consequence, the use of oil for electricity generation also shows a steady increase over the period, rising from its 1983 level of 28,000 toe to 53,000 toe in 1995 (Table 4.9).

Expanding use of gas oil for diesel generation in the external zones accounts for over 80% of the increase.

Table 4.8: PATTERN OF SUPPLY, 1985-1995
(Gross Generation)

	1983 (Actual)		1985		1990		1995	
	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)
Interconnected System	221.4	100.0	262.2	100.0	364.7	100.0	434.5	100.0
Thermal Generation	6.1	2.8	3.1	1.2	3.5	1.0	3.5	0.8
Hydro Generation	215.3	97.2	259.1	98.8	361.2	99.0	431.0	99.2
Other	138.8	100.0	139.9	100.0	155.8	100.0	188.2	100.0
Thermal	106.2	76.5	130.9	93.6	150.8	96.8	183.2	97.3
Hydro	32.6	23.5	9.0	6.4	5.0	3.2	5.0	2.7
Total	360.2	100.0	402.1	100.0	520.5	110.0	622.7	100.0
Thermal	112.3	31.2	134.0	33.3	154.3	29.6	186.7	30.0
Hydro	247.9	68.8	268.1	66.7	366.2	70.4	436.0	70.0

Source: JIRAMA.

Table 4.9: OIL CONSUMPTION FOR ELECTRICITY GENERATION, 1985-1995 ('000 toe)

	1983 (Actual)	1985	1990	1995
Fuel Oil	12.4	11.8	13.4	16.3
Gas Oil	15.7	26.1	30.4	36.6
Total	28.1	37.9	43.8	52.9

Source: JIRAMA.

Investment Program

4.15 The investment program for 1985-90 for the development of JIRAMA's facilities to meet the projected generation requirements is estimated at about FMG 64 billion at 1984 prices (equivalent to about US$102 million, of which about US$79 million would be in foreign exchange). As shown in Annex 39, and summarized in Table 4.10, the main focus is on transmission and distribution to improve the quality and reliability of supply. These two items account for about FMG 32 billion (51%) of the program shown, mainly for network extensions, but including FMG 3.5 billion for rehabilitation of existing distribution networks. The generation component of about FMG 26 billion (38%) is mainly (FMG 16 billion) for hydropower, including provision for rehabilitation of existing plants, for small hydro development and for studies of large schemes. The thermal power component of FMG 10 billion also includes provision for rehabilitation of existing diesel sets.

4.16 As indicated in Annex 39, the proposed investment program does not provide for any major new generating project. This is on the assumption adopted for the demand projection that there will be no major new industrial loads before 1995 (para. 4.4). However, the program does include provision for studies of the Ankorahotra and Ambodiroka hydropower projects. The former would represent a logical extension of the existing Andekaleka plant by constructing an upstream regulating high dam to create a seasonal storage reservoir, and adding two generating units at the existing powerhouse. Similarly, Ambodiroka appears to be the most attractive next project in the Mahajanga region, as and when required by the growth of demand. Studies by JIRAMA, with the assistance of consultants, have indicated that these projects would form part of the least-cost power development program, although they are unlikely to be required until the late 1990s.

Table 4.10: STRUCTURE OF INVESTMENT PROGRAM (JIRAMA)
1985-1990

	FMG (billions)	% of total program
Generation a/	25.9	40.5
Transmission	13.8	21.6
Distribution	18.6	29.1
Other	5.6	8.8
Total	63.9	100.0

a/ Rehabilitation and small hydro. Annex 39.

4.17 JIRAMA's investment program would have to be greatly increased if major new power-consuming industries, such as the suggested ferrochrome plant in the interconnected zone or the additional cement plant in the Mahajanga region (para. 4.5), were introduced. Construction of the Ankorahotra and Ambodiroka hydropower plants (para. 4.16), for example, in 1985-90 would more than double the investment requirements in this period from FMG 64 billion (US$102 million) to about FMG 132 billion (US$211 million, including US$165 million in foreign exchange). However, in the mission's view, the likelihood of major new power-intensive industries being established within the ICS in the foreseeable future is quite small. Thus, JIRAMA will have to service debt on the Andekaleka scheme throughout the next 10-15 years with relatively low utilization of this capacity. This fact has serious repercussions for JIRAMA's financial performance if tariff levels are not raised accordingly, and if quite economic uses, hence sales, of electricity are not found soon.

Supply Issues and Recommendations

4.18 The supply issues emerging from the review of the electric power subsector are as follows:

(a) The main issue is the large surplus of hydroelectricity in the interconnected system, which on present projections is unlikely to be fully utilized until near the end of the century. JIRAMA should examine the scope for accelerated utilization of this surplus within the interconnected system through substitution by electricity of other energy sources in household cooking, and for heat and steam raising in industry and commerce (para. 2.19).

(b) Because of the small loads and long distances between most of the external zones and the interconnected system, it would not be realistic to anticipate countrywide integration of all the zones. Nevertheless, the suggested study should consider the possibilities for the connection of further zones to the interconnected system. JIRAMA should also study the possibilities for hydropower schemes which could interconnect and serve regional groupings of presently self-contained power generating systems.

(c) Parts of the transmission system require strengthening to improve the supply. Recent analysis indicates that, in respect of supply to Antsirabe, an economic justification exists to construct a new 138 kV line as well as for strengthening the existing 63 kV transmission line; however, there may be serious funding difficulties for the major 138 kV line investment.

(d) The under-developed condition of parts of the distribution network, and over-designed house wiring systems (e.g., double wiring), in the interconnected system are an obstacle to the development of household consumption through wider use of appliances, for example rice cookers, should they prove economically viable (para. 4.6). In addition, JIRAMA is not able to keep up with the demand for connections because of a lack of materials. The mission therefore strongly endorses the proposal to finance rehabilitation and reinforcement of distribution to eliminate bottlenecks and reduce overloading of main feeders.

(e) The bagasse-fuelled steam power stations in the sugar industry are underutilized, operating only during the crop season (para. 4.8). This suggests the possibility of operating them throughout the year to displace diesel generation for public power supply in their neighborhood (para. 2.34). A French-financed study of sugar industry development will examine this possibility, and the results should be monitored and, if necessary, followed up.

(f) In sequence with the above-mentioned supply and demand analyses and the detailed demand forecast (para. 4.6), and as a vital input to estimation of the economic cost of supply, JIRAMA should undertake a detailed least cost expansion plan to meet the most likely scenario of projected capacity and energy demand on the interconnected system with and without the proposed ferrochrome demand.

(g) Diesel generation plant in the major supply centers should be audited and, if necessary, rehabilitated for sustained operation in the medium-term. Up until recently, several such plants were regarded as soon to be displaced, whether by new hydropower or interconnected with the main ICS. In reviewing engineering studies completed in 1985, the mission concludes that, for the time being, continued operation of existing thermal generation in these centers is probably the least cost supply option. In this case, improving thermal plant reliability and efficiency is a high priority.

(h) Integrated Study. The recommendations for transmission, distribution and generation rehabilitation made above can be dealt with in an integrated way by undertaking one overall "Power Sector Efficiency Audit" encompassing all power system efficiency improvements. 19/ Ideally, the prospects for utilization of surplus hydropower on the main ICS should also be examined as part of this analysis since supply and demand prospects and constraints are closely linked -- demand being subject to the cost and practicality of installing extensive new distribution networks.

Organization of the Power Subsector

4.19 Public electricity supply is the responsibility of the Malagasy Electricity and Water Corporation, known as JIRAMA, 20/ a state enterprise established by decree in 1975 to own and operate all public electricity and water supply facilities in Madagascar. Its eight-man Board of Directors, which is appointed by the Government, includes four members from various ministries who represent the interests of the state. Its present Chairman is a former Minister of Industry, Energy and

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19/ Field work for such a study was undertaken in March 1986, under the joint UNDP/World Bank Energy Sector Management Assistance Program. The results of this analysis will be available towards mid-1986.

20/ Acronym of its Malagasian name, Jiro Sy Rano Malagasy.

Mines. A Director General, also appointed by the Government, is responsible for the day-to-day management. 21/

4.20 Although under the formal jurisdiction of MIEM, JIRAMA seems to have enjoyed a reasonable degree of autonomy hitherto, without undue interference by Government officials in its affairs. However, it is subject to stringent control as regards foreign exchange allocations, which require the approval of MIEM, the Ministry of Finance and the Central Bank. The Government also exercises strict control over electricity tariffs (para. 6.8).

Institutional Issues

4.21 The main institutional issues in the electric power subsector are: 22/

(a) The lack of an effective system planning capability for making realistic demand projections and formulating development programs to satisfy the demand at least cost to the economy. At present, planning tends to be based on unrealistic load forecasts, inconsistent assumptions are used in evaluating projects, and the financial costs of projects are not adjusted to reflect their real costs to the economy. JIRAMA engaged Electricité de France (EDF) to carry out a system planning study, which was completed two years ago. No action appears to have been taken on its findings, which are summarized in Annex 41, or on updating in light of recent demand trends. 23/

(b) A specific aspect of the planning weakness is the lack of any clearly identified institutional responsibility for maintaining an inventory of potential major hydropower sites, with regular updating of technical characteristics and costs, which can be ranked in economic merit order for system planning purposes.

21/ The decree establishing JIRAMA also provided for the appointment of a General Controller, appointed by the Prime Minister, to ensure that JIRAMA functioned in accordance with the provisions of the decree and Government policy. However, this position has never been filled, and would appear to be superfluous while the Minister is Chairman of JIRAMA.

22/ Electricity pricing issues, which also have institutional implications (e.g., for JIRAMA's operational efficiency and financial performance), are dealt with in Chapter VI.

23/ It should be noted that as of 1986, a Directorate of Economic Studies and Planning had been created within JIRAMA. Thus, all planning functions have been regrouped, along the lines of Option 4 recommended by EDF (see Annex 41).

Responsibility for collecting the basic hydrological data appears to be dispersed amongst several agencies, including the National Meteorological Service and the Hydrogeology Division of MIEM. As the entity charged with public electricity supply, JIRAMA should be responsible for collecting and regularly updating the available information.

(c) The situation is even worse with regard to the potential scope for small hydropower schemes (i.e., below 1 MW), and for similar reasons. As already recommended (para. 2.40), there should be a review of small hydropower potential and, if this confirms the economic prospects, it should be followed by a study to determine, inter alia, the appropriate institutional arrangements for development.

(d) Liaison between JIRAMA and the Rural Infrastructure Directorate of the Ministry of Agricultural Production and Agrarian Reform appears to be weak. Close cooperation is necessary in order to ensure that rural energy planning takes adequate account of the alternative options, including rural electrification, with or without small hydropower, and is properly integrated with other aspects of rural development.

(e) Financial planning and management information systems in JIRAMA could be greatly strengthened, particularly by the recruitment and training of additional competent financial management staff to assist the present over-burdened staff.

(f) The weakness of management information systems partly reflects shortages of essential office equipment and supplies. JIRAMA does not have its own computer facilities, but relies on an affiliate known as SOMAGI 24/ for its main data processing requirements. The collection and processing of information within JIRAMA suffer both in quality and timeliness from a lack of minicomputers, electronic calculators and associated software.

Recommendations

4.22 The mission supports ongoing efforts under the existing IDA power credit to address the institutional weaknesses in the power subsector and the continuation of those efforts under the proposed second power project. With regard to the specific issues, the mission's recommendations are that:

(a) JIRAMA should adopt an urgent action program to strengthen system planning along the lines recommended in the EDF planning

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24/ Acronym for "Société Malgache de Gestion Informatique".

study of 1982. 25/ Their efforts should be supported by technical assistance for staff training (para. 4.24).

(b) JIRAMA should appoint a consultant to collate and review all available information on potential major hydropower sites and prepare a preliminary ranking in economic merit order. The consultant should also make recommendations on the action needed to update the cost and technical data as necessary on the individual sites and on any changes desirable in JIRAMA's internal organization, to ensure regular review and updating of the inventory of hydropower sites.

(c) A committee should be set up under the chairmanship of the Director of Energy of MIEM for the coordination of rural energy planning. This should include representatives of JIRAMA, the Rural Infrastructure Directorate of MPARA, the Directorate of Fisheries and Forests of MPAEF, the Directorate of Technological Research of MRSTD, IMI, the HERY VAO company and DUEN.

(d) The mission supports JIRAMA's engaging the services of consultants to carry out a diagnosis of its financial management and make recommendations for improvement.

(e) The mission supports the proposal to include provision for JIRAMA's needs in office equipment and supplies in the proposed IDA energy credit.

Manpower and Training

Issues

4.23 JIRAMA currently employs some 4,240 staff, compared with about 3,700 at its inception and a peak figure of 4,500 in 1981. It is not possible to say exactly how many staff can be attributed to the electricity, as distinct from the water supply function, because of the staff providing common services to both activities, but about half the total number are assigned to power operations. The main issues relating to manpower and training are:

(a) Because of the slowdown in investment activities connected with the large surplus of hydropower (para. 4.12), there is at present a surplus of high-level power engineering staff, despite a freeze on recruitment.

25/ As of early 1986, JIRAMA had started to take steps in this direction by establishing a Directorate of Economic Studies and Planning.

(b) There is also overmanning at the lower levels, although efforts are being made to correct this through a freeze on recruitment coupled with natural attrition.

(c) The training arrangements for accounting staff have been inadequate in the past, but the situation seems to have improved with the recent establishment by the Government of an Accounting Training Center.

(d) Shortage of foreign exchange has seriously impeded JIRAMA's ability in recent years to send professional staff abroad for training. This underlines the importance of including specific provision for training in project aid, as is proposed in connection with the second IDA project.

Technical Assistance

4.24 Technical assistance is required to strengthen JIRAMA's capabilities and reduce its heavy dependence on external consultants, particularly with respect to system planning. Specifically, training should be provided for at least three JIRAMA engineers/economists in the following areas:

(a) Load Forecasting: analysis of consumption patterns and characteristics, auditing of power consumption and requirements of direct power consumers, preparation of energy and capacity balances, and load growth modeling.

(b) Generation and Transmission Planning: least cost development programs, economic justification of projects, hydropower development master plans, fuel supply implications, cost data updating and procedures for financial arrangements.

(c) Power System Analyses: load flow studies, stability calculations, voltage fluctuations, network losses, loading of power facilities, selection of power system parameters and standardization of equipment.

In addition, JIRAMA needs to purchase a personal computer and software for numerical analyses and calculations. This equipment is estimated to cost US$34,000.

4.25 In light of renewed interest by the GOM in the ferrochrome industry, and acknowledging the long lead time for developing the strong system planning capability proposed in 4.22(a) above, technical assistance is also required urgently to help update the least cost expansion plan for the main ICS and for estimating the economic cost of supply for various scenarios of load growth. These scenarios should be set up both with and without the load envisaged for the most recent design of the ferrochrome industry.

4.26 Several of these technical assistance needs can be met at the same time, for example, by having consultants, who are assisting in updating the expansion plan also provide training to JIRAMA engineers and economists. It should be noted that, to establish priorities for investment in system rehabilitation (para. 4.18 (h)), UNDP/World Bank technical assistance is being provided for a power system efficiency audit for the main ICS and major supply centers.

V. REFINERY REHABILITATION

Introduction

Background

5.1 Madagascar's sole petroleum refinery, located at Toamasina, dates from 1966. Up to 1976 it was owned by a group of foreign oil companies (except for a 15% government holding) and operated by the French company ELF. Since 1976, when it was nationalized, it has been operated by the Malagasy Petroleum Refinery Company, known as SOLIMA, 26/ a 100% government owned company. It was originally built as a simple hydro-skimming refinery with a crude oil processing capacity of 10,000 barrels per day (bpd), but this was later increased to 16,800 bpd (about 750,000 tons per year (tpy)). The product mix of the refinery became increasingly out of balance with the pattern of domestic demand, yielding too much of the heavy products and not enough of the lighter products. To correct this, modifications completed in 1982 at a cost of some US$20 million provided a new 350,000 tpy visbreaking unit, a 165,000 tpy gas oil hydro-desulfurization unit and a 20,000 tpy bitumen unit. While this heavy investment program was under way, the refinery was starved of the foreign exchange needed for essential maintenance and spare parts. As a result, the general condition of the original refinery deteriorated rapidly and there was a succession of shutdowns, culminating in a final closure in September 1983 following a fire in the topping furnace.

Rehabilitation Studies

5.2 A June 1984 study by BEICIP ("Bureau d'Etudes Industrielles et de Cooperation de l'Institut Français du Pétrole") supported the findings of earlier analyses that rehabilitating the refinery was technically feasible and economically justifiable. The French "Caisse Centrale de Coopération Economique" (CCCE) therefore opened a line of credit of FF 43 million (US$4.8 million) for SOLIMA to: (a) finance a feasibility study which would define the project in detail and evaluate it on this basis; (b) purchase spare parts and catalysts needed to operate the refinery; (c) implement the most urgent rehabilitation measures; and (d) finance a thorough training program for the refinery operating staff. The refinery resumed operation in September 1984. The results of

26/ From its Malagasy name, Solitany Malagasy.

the feasibility study of the rehabilitation project, again by BEICIP, were available in October 1985. 27/

Factors in Evaluation of Project

5.3 As explained in BEICIP's feasibility study (October 1985), the objective of the rehabilitation project is to restore the refinery so as to permit its operation at its 1972 capacity of about 750,000 tpy. In addition, the BEICIP proposal allows for some minor modifications to improve the refinery's performance. Particular attention has been paid to increasing the yield of middle distillates, reducing losses and enhancing safety. The total cost of the rehabilitation and of the improvements is estimated at 1985 FF 140 million (approximately US$20.0 million).

5.4 To evaluate the rehabilitation project, BEICIP compared it with the alternative, which would be to shut down the refinery and import finished petroleum products for the domestic market. The main factors taken into account are the projected demand for petroleum products, the refinery margin, the expected international prices for crude oil and products, their respective import costs, product exports, technical improvements to the refinery, the capital costs of the rehabilitation project and the operating costs of the refinery.

Demand for Petroleum Products

5.5 Past Trends. The demand for petroleum products in the period 1973-1985 followed an erratic course (Annex 42). As shown in Table 5.1, between 1973 and 1976 overall demand fell by nearly 5% a year, the demand for all products except butane declining. It then rose at 7% a year in 1976-79, mainly because of sharp increases in demand for fuel oil and gas oil. This was followed by another decline between 1979 and 1985 of about 6% a year, mainly because of a large fall in demand for fuel oil. Over the period as a whole the average rate of decline was nearly 3% a year. The net result was that total demand in 1985 at 286,000 toe was 27% below the 1973 figure of 394,000 toe, the most significant falls being in fuel oil (53% below the 1973 level) and gasoline (35% lower). The pattern of demand has also changed, as shown in Table 5.1, the main features being the increased shares of the middle distillates (kerosene, jet fuel and gas oil) and the lower shares of gasoline and fuel oil.

27/ A cyclone struck the refinery in March 1986, causing about US$1.0 million worth of damage. The refinery has therefore been shut down for repairs, which are expected to last four months. This work is covered by SOLIMA's insurance policy and the rehabilitation project as defined by BEICIP has not been affected.

Table 5.1: DEMAND FOR PETROLEUM PRODUCTS, 1973-1985

	1973		1976		1979		1980	1983	1984	1985		Growth Rate a/			
	('000 toe)	(% share)	('000 toe)	(% share)	('000 toe)	(% share)	('000 toe)	('000 toe)	('000 toe)	('000 toe)	(% Share)	1973-76	1976-79	1979-85	1973-85
												--- percent p.a. ---			
Gasoline	87.9	22.3	84.1	24.8	86.6	20.9	84.4	59.9	55.8	57.0	19.9	(11.4)	1.0	(6.7)	(3.5)
Aviation Gasoline	b/		--	1.5	0.4	1.3	1.0	1.0	0.7	0.2	--	--	(11.9)	--	
Kerosene	] 50.0	] 12.7	33.3	9.8	31.7	7.6	29.9	30.4	27.1	28.7	10.0	--	(1.6)	(1.6)	(1.6) c/
Jet Fuel	]	]	16.8	5.0	23.7	5.7	23.1	18.6	17.7	19.6	6.9	--	12.1	(3.1)	1.7 c/
Gas Oil	152.6	38.8	126.8	37.3	156.8	37.7	157.8	127.0	126.4	129.8	45.4	(6.0)	7.3	(3.1)	(1.3)
Fuel Oil	99.4	25.2	73.4	21.6	110.1	26.5	91.3	49.9	39.9	47.1	16.5	(9.6)	14.5	(13.2)	(6.0)
Butane	4.1	1.0	5.1	1.5	5.1	1.2	5.1	2.6	2.6	3.0	1.1	7.5	0	(8.5)	(2.6)
Total	394.0	100.0	339.5	100.0	415.5	100.0	393.4	289.4	270.5	285.9	100.0	(4.8)	7.0	(6.1)	(2.6)

a/ Figures in parentheses are negative.
b/ not available or not applicable.
c/ 1976-85.
Source: SOLIMA.

5.6 The swings in demand shown in Table 5.1 partly reflect the fluctuating fortunes of the economy over this period (para. 1.3), but changing price policies have also played a part. Thus, consumer prices of all products except gasoline declined in real terms between 1973 and mid-1979, but they were subsequently allowed to rise sharply, resulting in prices by 1984 which were above average international prices, especially for gasoline (para. 6.4). The fall in demand for gas oil and fuel oil after 1979 partly reflects reduced power station consumption following the commissioning in 1982 of the IDA-assisted Andekaleka hydropower plant.

5.7 Projected Demand for Products. BEICIP based its projections of petroleum product demand from 1985 to 2000 on SOLIMA estimates. A high and a low demand scenario were calculated (Annex 43). The difference between the two is that, in the low scenario: (a) the Zeren fertilizer plant is shut down; (b) work on road projects is reduced to 40% of the high scenario figure; and (c) there is no tuna fleet market. In view of Madagascar's current economic situation, the low demand scenario seems more probable and is presented in Table 5.2.

Table 5.2: PROJECTED DEMAND FOR PETROLEUM PRODUCTS, 1985-2000

	1985 (actual)	1990	1995	2000	Growth Rate 1985-90	1990-95	1995-2000
	('000 toe)				percent p.a.		
Gasoline	57.0	59.7	61.6	64.8	0.9	0.6	1.0
Kerosene	28.7	28.8	31.8	35.2	0.1	2.0	2.1
Jet Fuel	19.6	17.5	18.4	19.4	(2.2)	1.0	1.1
Gas Oil	129.8	147.7	170.4	197.5	2.6	2.9	3.0
Fuel Oil	47.1	48.6	53.8	59.4	0.6	2.1	2.0
Butane	3.0	4.7	7.7	9.8	9.4	10.4	4.9
Total	285.9	307.0	343.7	386.1	1.4	2.3	2.4

Source: BEICIP, October 1985.

5.8 In the low scenario, total demand is projected to grow at somewhat over 1% a year from 1985 until 1990, and at above 2% a year in the 1990s. With respect to individual products, butane has the highest growth rate. Its consumption is expected to rise rapidly (about 10% a year from 1990 to 1995) because it will serve as a substitute for increasingly scarce fuelwood.

Crude Oil and Product Prices, Refinery Margin

5.9 The economic viability of the project depends essentially on the relative international prices of crude oil and petroleum products. These determine the "refinery margin", which is the difference between the crude oil cost and the value of the refined products. The refinery margin is expected to cover both operating and financial costs, and is a key criterion in assessing the project. BEICIP chose two sets of crude oil and product prices on which to base its analysis, the average prices (c.i.f. Toamasina) paid by SOLIMA in 1984 and in the first semester of 1985 (Table 5.3).

Table 5.3: CRUDE OIL AND PETROLEUM PRODUCT PRICES USED IN THE BEICIP FEASIBILITY STUDY

	1984 Average	First Semester 1985 Average
	(US$ per tonne, c.i.f. Toamasina)	
Crude Oil		
Arabian Light	225	217
Qatar	237	229
Petroleum Products		
Gasoline	312	302
Kerosene	321	303
Gas Oil	276	268
Fuel Oil	196	180

Note: Except in the case of fuel oil, all the figures reflect prices actually paid by SOLIMA. Since no fuel oil was imported in 1984 or early 1985, the fuel oil price is BEICIP's estimate.

Source: BEICIP, October 1985.

5.10 Except in the case of fuel oil, these prices are significantly higher than those prevailing at the time on the international competitive market. BEICIP estimates that, during each period, SOLIMA paid a surcharge of US$9 per tonne on crude oil, US$30 per tonne on gasoline and on kerosene, and US$20 per tonne on gas oil. If SOLIMA were to import fuel oil, BEICIP estimates that there would be no surcharge on it because it is available at a favorable price from the nearby refinery of Mombasa, which yields a large excess of this product. The higher charges are due to SOLIMA's restrictive credit terms (reflecting the foreign exchange shortage), i.e., 90 days' credit guaranteed by the Central Bank instead of the standard terms of 30 days' irrevocable credit guaranteed by a first rate international bank. Most suppliers are not prepared to accept these terms, so that SOLIMA is forced to operate in a very restricted market and pay penalty prices.

5.11 In April 1984, for example, of the six suppliers of petroleum products who responded to SOLIMA's invitation to bid, five stipulated the standard payment terms, so that SOLIMA was forced to deal with the sixth, who was the only one prepared to accept its payment terms. The prices charged by this supplier for the lighter products (gasoline, kerosene and gas oil) were on average about US$24 per tonne higher than those quoted by the lowest bidder. For the same reasons, the surcharge applies to freight as well as to the f.o.b. price. In April 1984, for example, SOLIMA paid a freight charge of US$1.65 per bbl of crude oil, as opposed to a normal rate of about US$1.18 at the time.

5.12 The penalty on the f.o.b. price of crude and products could be eliminated if SOLIMA were able to operate freely in the international market for petroleum products, but this is not considered a realistic option, since it would require a foreign exchange allocation to SOLIMA of some US$66 million. On the other hand, SOLIMA would need only a relatively limited foreign exchange allocation to achieve considerable savings in freight charges. This is because the normal freight charges for a 50,000 tonne shipload is only about US$0.5 million. For purposes of project analysis, BEICIP assumed that SOLIMA would keep paying its total surcharge the first three years of the project, but that it would then gradually be reduced to zero by the fifth year.

Product Exports

5.13 The economic viability of the rehabilitation project is also affected by the proportion of SOLIMA's output which is sold on the Malagasy market, as surplus products must be exported. The refinery has a regional export market (e.g., Mauritius, Réunion). In order to compete with products from the Persian Gulf, these products must be exported at prices which are less than the import parity prices on the Malagasy market by at least US$10 to 20 per tonne.

Technical Improvements

5.14 The SOLIMA refinery gives only 34% by weight of middle distillates (kerosene and gas oil). The improvements recommended in the BEICIP study would increase this proportion to over 40%, which is in line with the performance of a modern, well-equipped refinery. Similarly, the project as defined would lower refinery losses (including refinery fuel) from the current level of 8% weight on crude to 6%.

Project Justification

Main Results of the BEICIP Feasibility Study

5.15 BEICIP has compared the rehabilitation project with the alternative of importing finished petroleum products to determine whether it is the least cost way of meeting the projected demand for petroleum products. The alternative comprises only recurrent costs in the form of imported products. The proposed project comprises the capital costs of rehabilitating the refinery, plus the associated operating costs, which comprise the cost of the crude oil to be processed, the variable operating costs of the refinery and the cost of net product imports (i.e., the cost of products which still have to be imported, less the value of exported products).

5.16 Table 5.4 summarizes the results of BEICIP's analysis, for the two sets of petroleum prices considered and based on the treatment of Arab light crude to meet the low demand scenario.

Table 5.4: RESULTS OF BEICIP'S ANALYSIS OF THE REFINERY REHABILITATION PROJECT

	Average Oil Prices 1984	Average Oil Prices First Semester 1985
Refinery Margin, US$/T	14	9
Economic Rate of Return, %	26.4	10.0
Net Present Value, a/ US$ million	15.3	0.0

The figures are based on BEICIP's low demand scenario and on the treatment of Arab light crude.

a/ Discount rate of 10%.

Source: BEICIP, October 1985.

5.17 The project's attractive 26% rate of return under 1984 price conditions decreases significantly to a marginal 10% on the basis of prices from the first half of 1985. This underscores the sensitivity of the project's viability to changes in the relative prices of crude oil and petroleum products. As BEICIP points out, on average the refinery margin represents only a minor fraction, on the order of 5 to 10% at most, of the cost of crude or the value of products. Therefore, even a small change in the relative prices of crude and products can substantially alter the refinery margin and, consequently, the rate of return. 28/

Sensitivity Tests

5.18 BEICIP carried out sensitivity analyses for the main study parameters, including modifying crude costs, varying the investment costs, eliminating the surcharges, and treating exclusively Qatar crude. The test results confirm the importance of the relative prices of crude and products. A 2% increase in the price of crude reduced the rate of return by about 75%, while a 2% drop in the price led to a 60% improvement in the rate of return. Not surprisingly, the type of crude

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28/ Following the early 1986 sharp decline in world oil prices and the growing adoption of the concept of "refinery netback" pricing for crude oil, the refinery margin is likely to increase in relative terms for efficiently run refineries.

processed is another key factor. Refining Qatar crude, for example, resulted in a negative rate of return, i.e., a reduction by over 100% from the base case figure. In contrast, the project's viability is relatively insensitive to changes in the investment costs.

Modernizing the Refinery

5.19 As noted above, the BEICIP proposal does include measures to increase the yield of middle distillates. It is possible, however, to produce an even higher proportion of distillates, significantly improving the refinery's operating flexibility and profitability. This modernization would entail reorganizing and remodelling the visbreaking complex built in 1982, to upgrade surplus residual fuel oil into higher value distillates. With the modernization, 48,000 tonnes per year of fuel oil produced from a throughput of 500,000 tonnes of Arab light could be converted into an extra 37,000 tonnes of gas oil and 9,000 tonnes of gasoline, with 2,000 tonnes of fuel gas. It may therefore be possible for SOLIMA to meet the needs of its domestic market by processing less crude. The additional investment required is estimated at around US$8.0 million, with a payout period of about 2.5 years. The existing petroleum supply-distribution system should also be rehabilitated and modernized, at a further cost estimated to be on the order of US$4.0 million. A preliminary outline of this modernization proposal is given in Annex 44.

Recommendations

5.20 (a) The technical feasibility of the modernization proposal, and especially its effect on the overall viability of the rehabilitation project as defined by BEICIP, should be studied in greater detail. The analysis should be carried out with the low demand scenario as the base case. Particular attention should be paid to: the match between refinery output and domestic demand; the potential market for SOLIMA exports; the suitable crude for the refinery in light of SOLIMA's supply constraints; the implications for least cost petroleum product supply of enabling SOLIMA to operate freely in the international petroleum market, and appropriate foreign exchange/procurement arrangements; minimizing refinery losses through energy conservation measures; and especially, given the current uncertainty in the oil market, the project's viability under existing petroleum prices and the sensitivity of its rate of return to changes in them. The rehabilitation and modernization of the petroleum supply-distribution system should also be examined in detail under this study.

(b) SOLIMA should improve its procedures in the fields of refinery planning and operation process analysis. This will require technical assistance for special training of staff to (i) develop process data on each unit; (ii) obtain good data on yields and quality of all possible crudes for the refinery; and

(iii) write a computer program to help in the selection of type and quantity of crude to be processed and of products for export or import. This will require technical assistance (para. 5.28) at an estimated cost of FF 10 million (US$1.4 million).

Organization of the Petroleum Subsector

SOLIMA

5.21 The main agencies in the petroleum subsector are SOLIMA and the National Military Office for Strategic Industries (OMNIS). 29/ SOLIMA, which was established as a state enterprise in 1976 to take over the then existing oil companies (all affiliates or subsidiaries of foreign oil companies), is responsible for the importation and refining of crude oil, and the transportation, distribution and marketing of petroleum products. It comes under the jurisdiction of MIEM, and is managed by a Board of Directors appointed by the Government, which includes representatives of various Government departments. It operates with a large measure of autonomy in practice, but is subject to strict Government control in respect of foreign exchange allocations and petroleum product pricing.

OMNIS

5.22 OMNIS was created in 1975 as an autonomous state organism under the direct authority of the President of the Republic, with responsibility for defining national policy regarding military and strategic industries. Its role in the petroleum subsector derives from the fact that these industries specifically include hydrocarbons and tar sands, for which OMNIS takes the lead in exploration, research and development. OMNIS plays a similar role in relation to uranium and coal, and also controls two state enterprises responsible for ship construction and repair and chrome mining. It has also formed a joint venture with Bawden Drilling Company to supply goods and services to all the oil companies operating in the country.

5.23 OMNIS has entered into joint ventures with the private oil companies carrying out exploration. For this purpose it has created a subsidiary company called Akorama, which is the signatory to the contracts with the oil companies. At present Akorama exists only on paper and OMNIS acts on its behalf. In the event of a commercial oil discovery the petroleum legislation calls for the activation of Akorama to participate in any oil field development with the private companies. The timing of any institutional expansion and the definition of lines of

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29/ Acronym of its French name, "Office Militaire National pour les Industries Stratégiques".

authority and managerial control, as well as staffing procedures, will need to be studied carefully. Since the oil companies will be "operators" in the joint venture, the Government will need to avoid costly overstaffing and additional bureaucracy, which has occurred in other countries. These institutional issues will be considered in the context of the ongoing IDA oil exploration promotion project over the next year.

Institutional Issues

5.24 A number of institutional issues arise concerning SOLIMA, as follows:

(a) Although it enjoys considerable operational autonomy, the need for Government approval of foreign exchange allocations causes problems in the prevailing situation of scarcity. In recent years, for example, SOLIMA has been required to reduce stock levels of petroleum products well below the minimum level essential to avoid the risk of interruption in supplies to customers, especially in industry.

(b) Similarly, Government approval of proposed petroleum product price is prone to serious delays, with adverse consequences for SOLIMA's financial situation.

(c) Data processing appears to be a problem. SOLIMA relies on JIRAMA's affiliate SOMAGI (para. 4.22(g)) for its main data processing needs, such as accounts and payrolls, but experiences delays in having its work done, with the result that it is sometimes forced to do the job manually. This problem is compounded by a shortage of in-house computing aids, which also reflects the foreign exchange shortage. For example, SOLIMA urgently needs six small computers, but this requires Government approval of a foreign exchange allocation of FF 2.6 million (US$290,000).

(d) Partly because of these data processing deficiencies, there appear to be problems in the timely preparation of essential management information. This affects not merely the flow of information within SOLIMA but also the flow from SOLIMA to MIEM, which seems insufficient to keep the Minister properly informed on the up-to-date petroleum supply and demand situation. A weekly report is made on petroleum product stocks, but sales and import statistics, for example, are apparently presented only once a year on the occasion of submitting the proposed import program for the following year.

Recommendations

5.25 The mission recommends that:

(a) Government approval of needed price increases for petroleum products should be speeded up (para. 6.4);

(b) there should be an urgent review of SOLIMA's office equipment needs, especially for data processing and computing purposes. This could be carried out by the proposed energy adviser (para. 7.16); and

(c) SOLIMA's existing management information system should also be reviewed, including the present arrangements whereby SOLIMA is dependent on SOMAGI for its main data processing requirements.

Manpower and Training

SOLIMA

5.26 The main problems concern the refinery operating and maintenance staff, who have not been able to keep up-to-date with modern refinery technique and practice. This results from the takeover of the refinery by SOLIMA, coupled with the severe foreign exchange shortage and the installation of new equipment in 1982. Previously the French company ELF operating the refinery sent its staff regularly to France or elsewhere to keep them up-to-date, but SOLIMA has found it increasingly difficult to continue this practice. However, the problem should be alleviated by the provision for training under the recent French credit for refinery rehabilitation (para. 5.2).

5.27 SOLIMA staff need targetted training, rather than training across the board. This will be particularly true in connection with the installation of new equipment should the proposed rehabilitation and modernization be carried out. Among other things, SOLIMA will need to develop an expertise in refinery planning, for which it will require technical assistance.

Recommendation

5.28 Technical assistance is to be provided to SOLIMA under the French credit for training (para. 5.2). In the event that the refinery is rehabilitated and modernized, further technical assistance should be provided for specialized training of refinery staff, for example, in refinery planning in order to ensure optimum operation of the rehabilitated refinery. The estimated cost of FF 10 million (US$1.4 million) has been included in BEICIP's estimate for the rehabilitation project.

VI. ENERGY PRICING

6.1 Energy pricing is the chief policy instrument for Government to manage the demand for energy in the economy. In Madagascar, the following energy sources come in for consideration in this regard: petroleum products, electricity and woodfuels. 30/ The basic questions to be addressed are:

(a) Do the levels of domestic energy prices reflect the relevant economic cost of supply?

(b) Does the structure of domestic energy prices reflect the relative economic scarcities of domestic fuels, thus providing the right signals to consumers for efficient interfuel substitution?

(c) Are domestic energy prices sufficient to recover the relevant financial cost of supply?

Petroleum Products

6.2 Petroleum product prices are fixed by the Government, at the request of SOLIMA, the national petroleum refining and product distributing company. The guiding principles are to raise a certain amount of fiscal revenues as budgeted for each year and to ensure SOLIMA's financial viability. At the time of the most recent increase in domestic petroleum product prices (May 17, 1984), SOLIMA's refinery was out of commission and product requirements had to be imported. 31/ Thus, the c.i.f prices paid by SOLIMA for petroleum product imports represent an appropriate indicator of their cost to the economy at the time.

6.3 Information provided by SOLIMA on the composition of petroleum product prices begins at the "price ex-depot" stage (Annex 45). Table 6.1 extends this pricing formula by adding in the relevant c.i.f. prices as the starting point.

30/ Coal is excluded here as only small quantities are imported for use in a cement factory at the relevant international price (para. 3.12).

31/ The refinery has since then resumed operations at a reduced level in anticipation of its rehabilitation (Chapter V).

Table 6.1: COMPOSITION OF PETROLEUM PRODUCT PRICES AS OF MAY 17, 1984

Product	Units	c.i.f. Price a/	Net Tax	Ex-depot Price	Distribution Margin	Retail Price
LPG (Butane)	FMG/12.5 kg	3,799.5	2,450.5	6,250.0	250.0	6,500.0
Regular Gasoline	FMG/liter	132.9	239.1	372.0	10.0	382.0
Kerosene	FMG/liter	144.1	6.9	151.0	9.0	160.0
Gas Oil	FMG/liter	120.6	57.4	178.0	8.0	186.0
Fuel Oil	FMG/liter	92.5	29.0	121.5	-	-

a/ April 1984.

Source: SOLIMA.

In the absence of a breakdown of the difference between "ex-depot" and c.i.f. prices as to SOLIMA cost/profits and government taxes, this difference is taken to essentially represent "net tax" in the economic sense, i.e., the net take by the public sector (government and SOLIMA combined). While obviously forming part of the "net tax" item as here defined, unloading and related handling charges incurred by SOLIMA at the "depot" level presumably are negligible relative to the magnitudes of the differentials referred to.

6.4 Table 6.2 compares the c.i.f. prices paid by SOLIMA with the corresponding domestic product prices immediately prior to and upon the May 1984 price increase.

Table 6.2: RATIO OF DOMESTIC TO BORDER PRICES OF PETROLEUM PRODUCTS

Product	Units	c.i.f Price a/	Domestic Price		Domestic/c.i.f. Price Ratio	
			16 May '84 b/	17 May '84	16 May '84 b/	17 May '84 b/
LPG (Butane)	FMG/12.5 kg	3,799.5	5,500.0	6,500.0	1.4	1.7
Regular Gasoline	FMG/liter	132.9	323.0	382.0	2.4	2.9
Kerosene	FMG/liter	144.1	126.0	160.0	0.9	1.1
Gas Oil	FMG/liter	120.6	148.0	186.0	1.2	1.5
Fuel Oil	FMG/liter	92.5	94.1	121.5	1.0	1.3

a/ April '984.

b/ These prices were in effect as from May 17, 1982.

Source: SOLIMA.

It will be seen that already prior to the May 1984 increase domestic prices for petroleum products other than kerosene were equal to or above the c.i.f. prices, in the case of gasoline by as much as 140%. The May 1984 increase further widened these margins and significantly, eliminated the previously existing subsidy on kerosene. As a result of that increase, then, all domestic petroleum product prices fully reflected their economic cost. Since then (May 1984), however, the FMG has depreciated by about 20% (May 1985) vis-a-vis the U.S.$, the currency of the international oil trade. Hence another review of domestic petroleum product prices would appear to be indicated.

6.5 The variations in the excess of domestic product prices over their c.i.f. prices are of course due to the varying degrees of product taxation. Table 6.3 highlights the tax element of product prices as defined above (para. 6.3) by expressing it as a percentage of the relevant 'cost' prices (i.e., retail price minus net tax). What stands out are the highly discriminatory net tax ratios, varying from 5% for kerosene to nearly 170% for gasoline, with fuel oil at about 31%, gas oil at around 45% and LPG at about 61%. These wide differentials, of course, reflect government's income distribution policy in that products used mainly by high-income consumers are taxed heavily (e.g., gasoline) and vice versa (e.g., kerosene). The relatively low gas oil price in particular is linked to the Government's policy of mechanizing agriculture, of massive importation of diesel buses and trucks and of minimizing the cost of inputs to industry.

6.6 However, such stark price differentiation away from the relative economic costs of supply leads to inefficiencies in energy use in several respects. The relatively low price of gas oil (46% of gasoline) unduly favors diesel engine vehicles over gasoline driven ones as the former, under normal conditions, already are more fuel efficient than the latter. Yet diesel vehicles are comparatively more expensive to import; tend to do more damage to the roads because of heavier weight and result in greater air pollution particularly in urban areas, the social cost of all of which need to be considered. The very low relative price of kerosene (42% of gasoline, 85% of gas oil) provides a strong incentive to blend it heavily with gas oil and to a smaller extent, gasoline, such adulteration entailing additional wear and tear of the engines, and in the case of gasoline, less than efficient engine performance as well. Moreover, given the profile of domestic product demand relative to the domestic refinery's configuration, gas oil in particular is in short supply and needs to be imported whereas there is considerable spare capacity for the supply of gasoline. The price ratio of about 0.7 between fuel oil and gas oil, on the other hand, provides a sufficient incentive to use the former, which is in excess supply.

6.7 The mission lacked the necessary data to determine if petroleum product prices allowed SOLIMA to recover its costs. In general, however, SOLIMA would appear to recover them. As noted above (para 6.2), SOLIMA's financial viability is one of the criteria by which the domestic product prices are set.

Table 6.3: PETROLEUM PRICES, TAXES AND SUBSIDIES

Product	Units	16 MAY 1984				17 MAY 1984			
		Retail Price	Net Tax (Subsidy)	Cost Price	Net Tax (Subsidy) as % of Cost price a/	Retail Price	Net Tax	Cost Price	Net Tax as % of Cost price
LPG (Butane)	FMG/12.5 kg	5,500.0	1,500.5	3,999.5	37.5	6,500.0	2,450.5	4,049.5	60.5
Regular Gasoline	FMG/liter	323.0	181.1	141.9	127.6	382.0	239.1	142.9	167.3
Kerosene	FMG/liter	126.0	(24.1)	150.1	(16.1)	160.0	6.9	153.1	4.5
Gas Oil	FMG/liter	148.0	21.4	126.6	16.9	186.0	57.4	128.6	44.6
Fuel Oil b/	FMG/liter	94.1	1.6	92.5	1.7	121.5	29.0	92.5	31.4

a/ 'cost price' = retail price minus net tax (or plus net subsidy).
b/ Wholesale price.

Source: SOLIMA.

Electricity

6.8 For historical reasons, electricity tariffs in Madagascar are extraordinarily complex and difficult to administer. It was not until October 1975 that JIRAMA was created and the opportunity for internally consistent and economically rational electricity pricing arose. Prior to that time, power was generated and tariffs were established for each administrative district separately. However, to date no significant and unifying tariff structure and level has been implemented. Prices set and administered by different administrative districts vary widely, even if they are supplied from the same power system at the same generation costs. Moreover, the number of tariff classifications can exceed 20 for each administrative zone. In particular, for residential users, there are generally two tariffs, one for lighting and one for other uses. This requires costly double metering. Beyond the interconnected system, each of the numerous regional power systems also has its own tariffs. For the most part, tariff levels relate only coincidentally to actual costs of production and supply, and tariff considerations are primarily financial rather than economic. Tariff structure is also complicated by the addition of value added and municipal taxes, which vary between regions, and within regions, between consumer categories. Tariff formulation is hampered by inadequate power system expansion planning and demand forecasting, leading to an almost retrospective determination of required tariffs, taking into account crudely estimated financial requirements to meet, at a minimum, the variable costs of production and debt service on outstanding loans. Samples of present tariffs which illustrate the wide diversity in tariff levels are provided in Annex 46. The administrative burden of accounting for such a wide range and large number of tariffs is debilitating for JIRAMA and confusing for consumers, and without doubt presents an important constraint on improved financial management in the utility.

6.9 JIRAMA is well aware of the irrationality of the present, largely inherited tariff structure and of the need for sweeping tariff reform. For example, in January 1982, the Commercial Division promoted guidelines for electricity pricing in Madagascar which recognized the need for tariffs to reflect the full costs of supply, including, where appropriate, shadow prices. The concept of long run marginal cost pricing was also embraced along with the need to marry this practice with the utility's financial requirements. Regrettably, JIRAMA has been unable to implement significant tariff reforms despite the imposition of recent tariff increases to endeavor to meet financial covenants agreed with its principal borrowers. The result is administrative confusion and costly economic inefficiency. JIRAMA had drawn up simplified reference tariffs in 1982 which more closely reflected the costs of production and supply in each supply zone, and had intended to move through transitional tariffs towards their complete implementation by 1984/85.

6.10 The need for tariff reform is urgent, not only for the above-mentioned reasons but because it is evident that the huge hydropower surplus, which will prevail through the mid-1990s, offers some prospect of relief from mounting woodfuels prices, as well as of reducing the foreign exchange demand of imported oil. Incentive tariffs may have to be devised which encourage consumption in some sectors where hydropower is economically the cheapest alternative, but which maintain the financial integrity of the utility. For new major industrial loads, such as electrification of boilers, separate meters, even new feeders, will permit special tariffs to be applied without administrative difficulty. Obviously, tarification, distribution expansion and marketing of new consumption patterns in industry and households (e.g., for cooking) would have to be closely co-ordinated to achieve the desired outcome of significant additional electricity sales. This complex problem should be studied in detail as part of the proposed review of prospects for utilising hydropower surpluses on the main ICS.

Firewood and Charcoal

6.11 Firewood and charcoal prices are left to be determined in the market place, their regulation by government being impractical. Reflecting the increasing shortage of woodfuels, their prices have substantially risen in recent years. This is especially true in Antananarivo, the capital, where this shortage is most acutely felt: over the 1973-1984 period the real price for firewood increased by about 50% and that for charcoal by 30%, with 1984 current retail prices at FMG 22/kg and FMG 55/kg, or USċ3.5 and USċ8.8 equivalent, respectively (Annex 47). Even so current market prices for woodfuels are still significantly below their economic cost if the full replacement costs based on new fuelwood plantations are considered, the relevant economic costs being estimated at about twice as high for charcoal and nearly one-third higher for firewood respectively (Table 2.4). Given the widening gap between the demand and supply of woodfuels in Antananarivo, their prices in real terms are bound to further increase substantially. The pace and extent of this increase will largely depend on the implementation or otherwise of the various woodfuel supply/demand management measures recommended above (paras. 2.45 to 2.48).

Recommendations

6.12 The mission recommends the following priority actions:

(a) Top Priority Action. A thorough electricity tariff review should be carried out in parallel with a detailed review of demand forecasts for each of the major supply centers and the proposed least cost system expansion studies (para. 4.25). Furthermore, this review should propose a simplified tariff structure based on the marginal economic cost of supply, while ensuring that JIRAMA is self-supporting financially. In view of the anticipated excess hydro capacity over the next decade or so and JIRAMA's substantial debt service burden, it is recommended that the study should examine ways of increasing capacity and energy utilization, and hence revenue through appropriate pricing to industrial and residential consumers.

(b) High Priority Action. A study should be undertaken of the scope and quantitative importance of inefficient inter-transport fuel substitution in Madagascar and of the effects of a narrowing of the gasoline-gasoil-kerosene price differentials on the balance of payments, public finance and income distribution.

VII. ENERGY PLANNING AND INVESTMENT PRIORITIES

Energy Sector Planning

Lack of Coordination

7.1 As shown in the organization chart in Annex 49, numerous ministries and agencies are involved in the energy sector. This makes coherent coordination of their policies and programs difficult and there is a strong need to improve this situation so as to make national energy planning more effective. Under its decree, the Ministry of Industry, Energy and Mines (MIEM) is expected to exercise the coordinating function within the sector, but it has not been able so far to effectively take on this role. This is partly due to its relatively recent creation (July 1983), preoccupation with urgent day-to-day problems and understaffing in relation to its responsibilities. Its coordinating task is made more difficult by the fact that the National Military Office for Strategic Industries (OMNIS), unlike the other two main state organisms JIRAMA and SOLIMA, reports directly to the President of the Republic, without a defined link to MIEM. OMNIS has major activities in the energy sector (para. 5.21) and has been involved in energy planning (para. 7.2) prior to MIEM's creation.

Planning Weaknesses

7.2 The lack of comprehensive energy sector planning again largely reflects the limited capacity so far of MIEM to fulfill this role. The Energy Directorate of MIEM is responsible, according to its defined functions, for energy demand and supply studies, energy data collection and the preparation of short, medium and long-term plans. In practice, however, it lacks the resources for these activities. In the meantime, OMNIS got involved in energy planning, partly because it was designated as the executing agency for a national energy planning study funded by the first IDA petroleum exploration promotion credit. This was prior to the creation of MIEM which was part of the Ministry of Economy and Commerce at the time. Consequently, OMNIS, as the project entity under the IDA credit, was made responsible also for arranging this study, in which the Energy Service of the then Ministry of Economy and Commerce of course participated. Two of the findings of the study, which was completed in April 1982, were that an energy data bank should be established and an energy planning unit established. Again, since MIEM was still not in existence, OMNIS took on the task of setting up the energy data bank and energy planning unit. Progress has been slow, however, in preparing the data bank, which is needed as the basis for effective energy planning.

7.3 Although it had not been implemented at the time of the Bank mission (when the organization was as shown at Annex 50), a Government decree of May 1984 provided for a complete reorganization of MIEM. As shown in Annex 51, this divides the present single directorate for Mines and Energy into two separate directorates. The reorganization is obviously designed, inter alia, to strengthen MIEM in carrying out its tasks in the energy sector, but MIEM would benefit from technical assistance in implementing the new organization, particularly with regard to the planning function.

Options

7.4 The problems of sector coordination and energy planning are closely interrelated and need to be considered together in evaluating the different options for their solution. The four main proposals which have emerged are:

(a) to make MIEM the focal point, as it appears to be in principle under its decree, for coordinating energy programs and policies, and for energy sector planning as a whole;

(b) to set up a national energy commission, reporting to the President of the Republic, with the responsibility for formulating energy policy and coordinating activities within the sector, supported by a central energy planning unit;

(c) a variant of (b), according to which the sectoral committee for energy included as part of the proposed new structure for national economic planning (para. 7.7) would be responsible for coordination in the energy sector, with the assistance of a permanent energy planning unit; and

(d) to formally assign the national energy planning function away from MIEM to OMNIS.

7.5 The first option, of making MIEM effectively responsible for sector coordination and planning, has the merit of simplicity, and would also avoid the creation of another layer of organization in the energy sector. It may be that the proposed new organization of MIEM (para. 7.3) is designed to meet the requirement, although it is not clear from the outline so far available whether it would be suitable for this purpose. In any event, MIEM would need assistance to establish its authority and capability for the key planning role.

7.6 The second option, that only an organization directly answerable to the President of the Republic would have the necessary standing to exercise the coordinating and planning functions in the energy sector, was the finding also of the 1982 energy planning study by Motor Columbus. This recommended the creation of a Coordination Commission under the President, which would be political rather than technical in character, with representatives of all the ministries and agencies involved in the sector and of the various regions. It would be supported by an Energy Planning Center, under a Director General, with responsibility for all aspects of energy planning, including collection of basic data, preparation of demand projections, development of alternative supply scenarios, and establishment of standards and regulations for energy production and utilization. The Motor Columbus study, which was commissioned by OMNIS, also suggested that OMNIS could provide the nucleus of the Energy Planning Center, and should also direct the activities of the Coordination Commission.

7.7 The third option is the proposal by the Directorate General of the Plan (DGP) for a restructuring of national economic planning. This would create a "Conseil Superieur du Plan" (CSP), under the President of the Republic, supported by "sectoral committees" for the main sectors of the economy. The CSP would include representatives of ministries, state enterprises, provincial Governments, the private sector and workers, with a secretariat provided by DGP. The sectoral committees, including one for energy, would formulate sector policies and coordinate sector activities. Outside the CSP and the sectoral committees, the new planning structure provides for a "planning cell", or central policy and planning unit, in each ministry, with responsibility for sector planning, the preparation of the sector program and liaison with CSP, DGP and the relevant sectoral committee. Assuming this new planning structure is duly set up, a separate energy commission would clearly be superfluous, but the sectoral committee for energy, which would not be sitting permanently, would need a strong permanent technical secretariat to be effective. The existing energy planning section in OMNIS (para. 7.2) could provide the nucleus of this secretariat.

7.8 The fourth option, of formally assigning the national energy planning function to OMNIS, would have the advantage of building on an already existing nucleus of energy planners in what is a resourceful and well managed organization whose head reports directly to the President. For this solution to be workable, however, MIEM's responsibilities for the energy sector would need at least in part to be transferred to or shared with OMNIS, thus creating an additional layer of organization in the sector.

Recommendation

7.9 The mission does not feel to be in a position to express a view on which one of the aforementioned options for institutionalizing national energy planning may be the most appropriate in the political context of Madagascar. It does recommend, however, urgent consideration and early decision by Government on the establishment and implementation of appropriate institutional arrangements to ensure effective energy sector coordination at the national level, with particular emphasis on integrated energy investment planning according to the principles of minimizing the relevant economic cost. To this end the mission recommends specifically that an energy adviser to the Government be appointed for a period of two years to help in setting up such arrangements and making them work. He should be an economist, or engineer-economist, experienced in all aspects of energy planning. He would be attached to whichever agency is chosen to take on the lead role. His main task would be to advise on the staffing and terms of reference of the central national energy planning unit wherever its administrative locus may be. He would also advise on any changes necessary, particularly in relation to investment planning, project evaluation and monitoring, the management information system, equipment needs (including office equipment) and staff training.

Manpower

7.10 The main general manpower issue is the lack of any long-term manpower planning, in the sense of any systematic attempt to project future manpower requirements in the energy sector, particularly of qualified professional staff and technicians, with the object of trying to match the supply to the projected demand. The main institutions of higher technical and scientific education (the polytechnics for engineers and the two "establishments" for natural scientists and agricultural scientists respectively) serve the needs of all sectors, not only the energy sector, and there do not seem to be any formal arrangements to take account of energy sector needs in planning their programs and intakes. The Ministry of Higher Education is now trying to remedy this situation by promoting the establishment of "conseils d'orientation" in institutions of higher education, which would bring together the administrators of the institutions and representatives of employers in the various sectors of the economy to discuss future requirements. The Government has also accepted in principle a proposal to establish a "Conseil National Technique pour l'Enseignement", which would include representatives of the educational institutions and of employers. One of its tasks would be to collect more reliable statistics on the requirements and supply for the various types of professional staff. In this connection, each agency in the energy sector should be required to produce a long-term manpower plan, to be updated annually, for consolidation by MIEM into a sector plan and submission to MES and DGP.

7.11 Another general problem is that professional technical staff in the energy sector tend to be seriously out of date regarding the latest developments in their professional specialities. This reflects the severe squeeze on recurrent budgets in recent years and the consequent cutbacks on the acquisition of technical journals and books and in provision for refresher courses, attendance at seminars, symposia and the like. This problem needs to be addressed by suitable technical assistance in connection with specific projects.

Training

7.12 The severe restrictions on recurrent expenditures in recent years have been accompanied by greatly reduced provision for training in the energy sector. Some agencies in the sector have been making little, if any, provision for training, resulting in a steady erosion of formal training programs and extension services. One consequence has been the inability of technical staff to keep up-to-date with developments in their field (para. 7.11).

7.13 There does not appear to be any formal training program for energy staff in MIEM, and the responsibility for organizing training is not clear. Training of professional staff in the Energy Service has not had a sufficiently direct relation to work responsibilities. More relevant overseas training opportunities are often not taken for lack of foreign exchange (e.g., for airfares).

Technical Assistance Needs

7.14 The priority areas for technical assistance for energy planning are:

(a) strengthening energy sector planning by the appointment of an energy adviser to the Government for two years, at an estimated cost of US$150,000 (para. 7.9);

(b) finance for the purchase of essential office equipment, including mini-computers, for the Energy Directorate of MIEM, at a cost estimated provisionally at US$250,000; and

(c) short-term consultancies, e.g., for training in areas of specific interest, as identified by the energy adviser. Estimated cost US$100,000.

Energy Sector Investment Requirements

7.15 Table 7.1 draws together a priority ranked energy sector investment program for 1986-1990, based on the investment proposals and recommendations presented in this report. This is the mission's view of priorities, based strictly on economic criteria. The five-year program proposed by the mission totals US$138 million equivalent, including nearly US$10 million for technical assistance and studies shown separately in Table 7.2. This proposal is intended as a basis for the Government's own public sector investment programming so far as energy is concerned, the account being taken of the availability of investible resources economy wide. Top priority investments amount to US$46 million of this total, high priority ones to US$41 million and those of lower priority to US$31 million; the refinery rehabilitation project (US$20.0 million) has not been ranked, pending a detailed analysis of the effect of the proposed refinery modernization on the viability of the rehabilitation project (para. 5.20). The top and high priority investments aim mainly at improving the increasingly precarious supply of household fuels, particularly in the Antananarivo region, while at the same time utilizing some of the large excess hydroelectric capacity that exists in the interconnected system.

7.16 The proposed technical assistance and studies (Table 7.2) are either project specific in that they help prepare and/or implement specific projects, e.g., training of charcoalers for the top priority Haut Mangoro carbonization project; or they are prerequisite to energy sector planning more generally, e.g., forest inventory studies and energy sector institutional support. Virtually all the technical assistance and studies here proposed, therefore, are of immediate priority.

Table 7.1: PROPOSED ENERGY SECTOR INVESTMENT, 1986-1990

Project or Program	Estimated Cost ('000 US$ 1984 prices) a/
Top Priority	
Household Fuels	
Carbonising of Haut Mangoro Pine Waste, Logging and Sawmill Residues	2,531 a/
Rural Afforestation	2,250
Rice Husk Briquette Production - Antananarivo	282 a/
Power Sub-Sector	
Cooking Electrification	1,438 a/
Distribution - existing and new centers	27,032 a/
Miscellaneous (materials, tools and others)	8,112
Energy Sector Institutional Support	
Manpower Training and Development	530
Energy Planning Assistance	500
Forest Inventory Study	2,500
Lac Aloatra Energy Development Plan	530
Sub-Total	45,705
High Priority	
Household Fuels	
Coppice Management Improvement	700
Fuelwood Plantations	9,375
Cooking Efficiency Programs	2,530
Cooking Fuel Demand Surveys	320
Power Sub-Sector	
Antananarivo - Antsirabe Transmission	4,771
Andekaleka - Tamatave Transmission	14,158
Micro-centrales Hydropower	8,848
Sub-Total	40,702
Lower Priority	
Household Fuels	
Lac Aloatra Rice Husk Briquettes	144
Power Sub-Sector	
Ambodiroka - Mahajanga Transmission - Preparatory	640
Ambodiroka Hydropower - Preparatory	797
Ankorahotra - Studies	272
Thermal Power Plants - Isolated Centers	14,256
Hydropower Plants - Others	14,048
Transmission - Others	1,482
Sub-Total	31,639
Not Ranked	
Refinery Rehabilitation	20,000 b/
TOTAL	138,046

a/ Includes technical assistance and studies shown separately in Table 7.2.
b/ Includes technical assistance and studies shown separately in Table 7.2. The rehabilitation project has not been ranked, pending detailed analysis of the effect of the proposed modernization on the project's viability.

Sources: Annexes 12, 39.

Table 7.2: PRIORITY TECHNICAL ASSISTANCE AND STUDIES INCLUDED IN THE PROPOSED ENERGY SECTOR INVESTMENT, 1986-1990

Project or Program	Estimated Cost ('000 US$ 1984 prices) a/
Carbonization Program	
Training of Charcoalers Haut Mangoro	600
Rice Husk Briquetting - Antananarivo	50
Upgrading Traditional Charcoaling	48
Household Cooking	
Cooking Electrification Review	50
Cooking Efficiency Programs	2,530
Cooking Fuel Demand Surveys	320
Forest Inventory Studies	2,500
Lac Aloatra Energy Development Plan	530
Power Sub-Sector	
System Expansion Studies Including Tariff Review	250
Ankorahotra - Studies	170
Refinery Rehabilitation	
Technical Assistance (Specialized Training)	1,100
Computers	290
Energy Sector Institutional Support	
Manpower Training and Development	530
Energy Planning Assistance	500
TOTAL	9,468

Sources: Annexes 12, 39.

NATIONAL ENERGY BALANCE, 1979
(Thousand TOE)

	PRIMARY ENERGY								Petroleum Products								
	Fuelwood a/	Bagasse b/	Solar, Wind	Hydro c/	Coal	Crude Oil	Charcoal	Electricity	LPG	Avgas	Gasoline	Kerosene	Jet Fuel	Gas Oil	Fuel Oil	Total	Line Totals
Gross Supply																	
Production	1,464.8	2.9	0.1	29.4													1,497.2
Imports					12.0	358.8				2.0	27.4		22.4	88.8		140.6	511.4
Primary Exports																	
Stock Changes									0.7			1.0					1.7
Total Available	1,464.8	2.9	0.1	29.4	12.0	358.8			0.7	2.0	27.4	1.0	22.4	88.8		142.3	2,010.3
Conversion																	
Petroleum Refining						(333.2)			4.4		59.2	33.5		68.0	168.1	333.2	0.0
Charcoal Production d/	(99.8)						99.8										0.0
Electric Power Generation																	
-- Public				(29.4)				78.0						(28.6)	(20.0)	(48.6)	0.0
-- Auto		(2.9)						11.9						(9.0)		(9.0)	0.0
Conversion Losses	(290.2)					(25.6)		(11.9)									(327 7)
Transmission/Distribution Losses e/								(6.2)									(5.2)
Energy Sector Use								(2.1)									(2.1)
Net Supply Available	1,074.8		0.1		12.0		99.8	69.7	5.1	2.0	86.6	34.5	22.4	119.2	148.1	417.9	1,674.3
Secondary Exports													(22.4)				(22.4)
Bunker Sales															(85.0)		(85.0)
Net Domestic Consumption	1,074.8		0.1		12.0		99.8	69.7	5.1	2.0	86.6	34.5		119.2	63.1	310.5	1,566.9
Consumption by Sector																	
Industry, Agriculture and Others			0.1		12.0			52.7	1.2					40.6	21.9	63.7	128.5
Transport										2.0	88.1			73.3	41.2	204.6	204.6
Households	1,074.8						99.8	17.0	4.2			34.5				38.7	1,230.3
Discrepancy and Rounding Errors									(0.3)		(1.5)			5.3			3.5

a/ Fuelwood is converted at 3,200 kcal/kg at 25% moisture content.
b/ 1980 data.
c/ Converted on thermal replacement basis (1 GWh = 250 toe).
d/ Charcoal is converted at 7,082 kcal/kg.
e/ Transmission and distribution losses are probably higher than those reported.

NATIONAL ENERGY BALANCE, 1983
(Thousand TOE)

	PRIMARY ENERGY								Petroleum Products							
	Fuelwood a/	Bagasse b/	Solar, Wind	Hydro c/	Coal	Crude Oil	Charcoal	Electricity	LPG	Avgas	Gasoline	Kerosene	Jet Fuel	Gas Oil	Fuel Oil	Total	Line Totals
Gross Supply																	
Production	1,675.8	2.9	0.1	62.0													1,740.8
Imports					7.5	210.2			0.6	1.5	6.2	5.0	18.4	12.5		44.2	261.9
Primary Exports																	
Stock Changes									0.7		9.1	2.9		68.0		80.7	80.7
Total Available	1,675.8	2.9	0.1	62.0	7.5	210.2			1.3	1.5	15.3	7.9	18.4	80.5		124.9	2,083.4
Conversion																	
Petroleum Refining						(201.1)			1.3		44.6	22.7		55.5	77.0	201.1	0.0
Charcoal Production d/	(121.3)						121.3										0.0
Electric Power Generation								-									
-- Public				(62.0)				90.1						(15.7)	(12.4)		0.0
-- Auto		(2.9)						11.9						(9.0)			0.0
Conversion Losses	(352.7)					(9.1)		(11.9)									(373.7)
Transmission/Distribution Losses e/								(8.2)									(8.2)
Energy Sector Use								(3.7)									(3.7)
Net Supply Available	1,201.8		0.1		7.5		121.3	78.2	2.6	1.5	59.9	30.6	18.4	111.3	64.6	288.9	1,697.8
Secondary Exports													(18.4)			(18.4)	(18.4)
Bunker Sales															(29.2)	(29.2)	(29.2)
Net Domestic Consumption	1,201.8		0.1		7.5		121.3	78.2	2.6	1.5	59.9	30.6		111.3	35.4	241.3	1,650.2
Consumption by Sector																	
Industry, Agriculture and Others			0.1		7.5			56.5	0.6					47.9	17.2	65.7	129.8
Transport										1.5	58.3			63.4	18.2	141.4	141.4
Households	1,201.8						121.3	21.7	1.7			28.6				30.3	1,375.1
Discrepancy and Rounding Errors									0.3		1.6	2.0				3.9	3.9

a/ Fuelwood is converted at 3,200 kcal/kg at 25% moisture content.
b/ 1980 data.
c/ Converted on thermal replacement basis (1 GWh = 250 toe).
d/ Charcoal is converted at 7,082 kcal/kg.
e/ Transmission and distribution losses are probably higher than those reported.

PETROLEUM EXPLORATION AND PROSPECTS

Hydrocarbon-related Geology

1. Madagascar has long been known as a country with prospects for commercial oil or gas discoveries. All the elements for oil generation and accumulation exist to some degree; thick sedimentary sections, plentiful structures (mainly fault-related) and surface oil shows in the form of tar sands and heavy oil indicating the presence of hydrocarbon sourcebeds. The geology of the region is complicated, however, by the existence of impermeable igneous dykes which cut across prospective formations. In addition, the search for traps likely to hold hydrocarbons is made difficult by the presence of numerous faults and of rapid facies changes, both in space and in time.

2. Nearly three quarters of Madagascar consists of an old crystalline core. This igneous area is flanked by two sedimentary basins which are prospective for oil and gas. The largest of these is in the west, the Morondava basin, and the other is in the north, the Mahajanga basin. The total sedimentary land area of these basins is 170,000 km^2. Both basins extend offshore under the Mozambique Channel. The shelf area (0-200 m) is 80,000 km^2; the deep water area (200-2,000 m) covers another 50,000 km^2 and may be found to be prospective in future years. There are also small sedimentary areas in the extreme south of the country and offshore over a narrow zone along the east coast, but these are not considered as prospective as the Morondava and Mahajanga basins.

3. Both these two basins contain sediments of continental and marine origin. The oldest formations, those of the Karoo series, crop out near the igneous basement edge along the central-west part of the country and generally are non-marine. They are regionally very widespread covering much of southern Africa and can be counted on to underlie the entire west and north coast of Madagascar. Moving seaward from the igneous outcrop, layers of younger sediments appear — Jurassic, Cretaceous and, finally, Tertiary along the coast. This wedge of younger sediments, formed primarily by marine deposition, thickens seaward from about the middle of both the Morondava and Mahajanga basins to become 6,000-7,000 m thick and continues offshore. The beds have been interrupted in numerous places, however, by major faults which have permitted a great thickness of older Karoo sediments to accumulate in long troughs.

4. Conventional wisdom in oil exploration would normally decree that the coastward halves of both the Morondava and Mahajanga basins, that part covered by marine sediments, would be the more prospective. This view is altered, however, by the fact that the Karoo contains widespread and thick deposits of bitumen-saturated sandstone and heavy oil. These occur in the outcropping sands and shales at Bemolanga, at the northern interior end of the Morondava basin, and further south near the Tsimiroro horst block. Such shows greatly enhance prospects for the Karoo, and they indicate hydrocarbon sourcebeds, albeit of unknown origin.

Exploration History

5. Most exploration in the country to date has been carried out in the Morondava basin, where the tar sand and heavy oil shows have been found. Seismic and drilling programs were undertaken during several periods beginning as early as 1902. Most of the early exploration was in the Bemolanga-Tsimiroro region. After World War II, exploration expanded to other areas as companies moved westward and northward toward the coast to explore the Karoo and younger formations in the subsurface in the hope of finding light oil. During the period 1965-74, five major international oil companies and six independents took up acreage and undertook some exploration in Madagascar. While favorable stratigraphy and hydrocarbon shows (both oil and gas) were encountered, no discoveries were made during the limited drilling which was done. Many of those wells were drilled prior to the advent of modern seismic techniques (great technical progress has been made in the last ten years); hence, only a few wells tested targeted stratigraphic traps, and some were not drilled sufficiently deep to test all possible accumulations. By 1975, however, most companies had left the country, preferring to concentrate funds and manpower on the large successful finds in the North Sea and Far East than in Madagascar, where no discoveries had yet been made, costs were high and the political climate toward foreign investment had changed. Yet, to many people in the oil industry, it was clear that more work was needed before the production potential of Madagascar could be confirmed or refuted.

Exploration Promotion

6. By 1980, in the wake of major oil price increases in 1979, the Government sought to stimulate oil exploration again in the country. In view of the high risk involved and the lack of experienced personnel, the Government decided to entrust exploration of conventional light oil to foreign oil companies having the necessary tehnical, financial and manpower resources. The Office Militaire pour les Industries Stratégiques (OMNIS), in charge of strategic resources in the country, was given authority for implementing this exploration strategy and entering into joint ventures with private oil companies. 1/ OMNIS was also mandated to continue its study of the heavy oil accumulation at Tsimiroro and the Bemolanga tar sands with a view to assessing their commercial potential. To support Government policy, IDA made a US$12.5 million credit to the Government of Madagascar in May 1980 for an oil exploration project. The project's principal objective was to provide the technical and legal assistance to support the Government as it sought to attract private oil companies to undertake exploration in the country.

1/ Through the creation of a subsidiary company, called Akorama, the entity which is the signatory to the contracts with the private oil companies. At the present time, Akorama is a paper company with OMNIS acting on its behalf.

7. With the assistance of legal consultants, OMNIS prepared a petroleum code and a fiscal framework, which was finally enacted in November 1980. In June 1980, OMNIS distributed widely a geological report in collaboration with Petroconsultants and put up four blocks for exploration contracts. Industry response was good; ten companies made proposals. In December 1981, OMNIS signed exploration contracts with two major oil companies, Mobil and Occidental Petroleum; the contracts covered acreage of 36,000 km^2 offshore and 21,500 km^2 onshore respectively in the Morondava basin. AGIP then signed an exploration contract with OMNIS in April 1982, covering acreage both onshore and offshore totalling 22,400 km^2 in the Mahajanga basin in the north. Finally, Amoco signed a contract in July 1982 for acreage covering 22,650 km^2 onshore, again in the Morondava basin. Subsequently, in 1983, Amoco signed agreements for yet additional acreage: in the Belo/Manja block to the southwest (20,500 km^2) and on a small strip to the east of its original holdings (4,700 km^2). OMNIS's participation in all these contracts is 51%; it is "carried" during exploration, however.

8. The 4 oil companies have far exceeded their original contract obligations; as of November 1984 a total of US$90 million had been spent on exploration. Three of the companies have finished their seismic obligations and are entering the drilling phase. Consequently, total additional expenditures through mid-1988 are expected to be close to US$100 million.

9. In June 1984, Mobil took up its option to enter the "second phase" of the contract which calls for the drilling of one well in 1985; this well was spudded in June 1985. Other wells are optional. In July 1984, Occidental concluded an agreement with Union of California for a 50% participation in Oxy's holding, thus assuring Oxy's entry into the drilling phase of its contract; again one well is obligatory. A seismic program of 2,552 km was completed in August 1985. Drilling is expected for 1986.

10. Amoco's program has been by far the most ambitious. Its original contract on the Serinam Sud and Serinam Nord blocks included an obligation to drill three wells. In its subsequent agreements to take up additional acreage, Amoco has taken on further seismic obligations as well as commitments to drill 2 additional wells. Amoco finished two wells, Namakia and Sarananala, both dry holes. A third well, Manambolo, was spudded on June 1, 1985, and a fourth location is under preparation.

11. AGIP completed a seismic program of 1,311 km in May 1985. While they have not yet announced any drilling plans, the technical results onshore are encouraging. Offshore drilling is not ruled out, but the company perceives it to be gas prone and does not expect gas to be commercial in Madagascar in the foreseeable future.

Tar Sands Research

12. In early 1981, the Government asked IDA to join with the European Investment Bank (EIB) in financing the study of a promising bitumen extraction process for the Bemolanga tar sands. Considerable work financed by EIB had already been done on the geology of the region and on processes for mining the sandstones which would be the first step in exploiting the resource. IDA agreed to reallocate US$500,000 from the promotion project to finance such a study. OMNIS hired INGECO, an Italian firm, to test its proprietary hot water process for bitumen extraction on the Malgache tar sands and to study the necessary on-site upgrading of the bitumen. The company submitted its final report in September 1982. AN EIB-financed study of the mining and crushing phase was also comp'ted at that time. The studies showed that extraction of the bitume. was not economically feasible at presently forecast oil price levels and with the currently available technology and high costs of extraction (as Bemolanga is in a remote part of the country). OMNIS, on its own, continues to identify and consider new processes which might eventually make oil extraction from the sands economical. This is a very long-term prospect, however, given present circumstances in the world petroleum market.

The Tsimiroro Heavy Oil Deposits

13. The heavy deposit at Tsimiroro has been known since the early 1900s, and several oil companies have drilled in the area, the last one being Chevron in the early 70s. Although valuable stratigraphic and petrographic data were obtained and a number of heavy oil impregnations were found as a result of these efforts, insufficient coring and testing were undertaken to confirm with any certainty the deposit's potential to produce hydrocarbons in sufficient quantity to justify development. Hence OMNIS' heavy oil consultants, D&S of Canada, recommended the core drilling and testing of ten wells in potential oil-bearing formations located throughout the Tsimiroro area in order to identify those areas with the potential for free flowing or steam-induced oil production and to undertake a complete analysis of reservoir properties. OMNIS initially sought private oil company participation in this effort but could not find a partner; several of the companies indicated their decision was based on lack of sufficient data on the deposit. In view of the need for more reservoir and production data to attract private investment, the drilling program was ultimately financed by IDA under the Tsimiroro heavy oil exploration project.

14. During the 1983 drilling program, eight wells were drilled, completed and tested; because of the onset of the rainy season it was impossible to drill all ten wells. Oil saturation in the areas drilled unfortunately was poor; all the reservoir sands had been flushed by migrating waters. Thus, no recoverable oil reserves were proved. However, the laboratory tests on stead flooding of core samples indicated that the reservoir characteristics were good and suitable for steam injection; heavy oil could be recovered from the sands using steam

injection if oil saturation of the sands was greater than 60 percent. During the dry season in 1984 OMNIS conducted an additional program which included the drilling of four shallow coreholes and coring prospective intervals for lab analysis. A further seismic program in the Tsimiroro area of about 100 km will be carried out during the 1985 dry season, and depending on its results, a drilling program of about 10 shallow core holes in 1986. The objective of this final phase of the project is to try to establish areas of higher oil saturation.

PROJECTED SUPPLY-DEMAND BALANCE FOR HOUSEHOLD ENERGY, ANTANANARIVO FARITANY
(thousand tons of wood equivalent)

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Urban Population ('000)	691,5	726,0	762,3	800,4	840,5	882,5	926,6	972,9	1,021,6	1,072,7	1,126,3	1,182,6	1,241,7
Rural Population ('000)	2,184,5	2,243,5	2,304,1	2,366,3	2,430,2	2,495,8	2,563,2	2,632,2	2,703,4	2,776,4	2,851,4	2,928,4	3,007,4
Total Population ('000)	2,876,0	2,969,5	3,066,4	3,166,7	3,270,6	3,378,3	3,489,8	3,605,3	3,725,0	3,849,1	3,977,7	4,111,0	4,249,2
Total Energy Demand ('000twe)	2,111,4	2,189,4	2,270,4	2,344,3	2,420,6	2,499,5	2,581,1	2,665,4	2,752,6	2,842,8	2,936,0	3,032,3	3,132,0
	0,01 "élasticité" from 1985 on.												
Sustainable Supply													
Antananarivo Faritany													
From Plantations ('000twe)	329,92	323,59	317,38	311,29	305,33	299,48	293,76	288,14	282,64	277,25	271,97	266,79	261,72
From Forests ('000twe)	45,82	45,82	45,82	45,82	45,82	45,82	45,82	45,82	45,82	45,82	45,82	45,82	45,82
Toamasina Faritany													
From Plantation ('000twe)	129,60	129,60	129,60	129,60	129,60	129,60	129,60	129,60	129,60	129,60	129,60	129,60	129,60
From forests ('000twe)	281,51	281,51	281,51	281,51	281,51	281,51	281,51	281,51	281,51	281,51	281,51	281,51	281,51
Total Sustainable Supply ('000twe)	786,9	780,5	774,3	768,2	762,3	756,4	750,7	745,1	739,6	734,2	728,9	723,7	718,7
Existing Modern Fuels													
Electricity ('000twe)	9,1	9,6	10,0	10,5	11,1	11,6	12,2	12,8	13,4	14,1	14,8	15,6	16,3
LPG ('000twe)	62,4	65,5	68,8	72,3	75,9	79,7	83,7	87,8	92,2	96,8	101,7	106,8	112,1
Kerosene ('000twe)	9,7	10,2	10,7	11,3	11,8	12,4	13,0	13,7	14,4	15,1	15,8	16,6	17,5
Sub-Total ('000twe)	81,2	85,3	89,6	94,1	98,8	103,7	108,9	114,3	120,0	126,0	132,3	139,0	145,9
Urban Trees and Woody Residues ('000twe)	63,3	65,7	68,1	70,3	72,6	75,0	77,4	80,0	82,6	85,3	88,1	91,0	94,0
Deficity Without Intervention ('000twe)	1,180,0	1,257,9	1,338,4	1,411,7	1,487,0	1,564,4	1,644,1	1,726,1	1,810,4	1,897,3	1,986,6	2,078,7	2,173,5
Deficit in ha equivalent ('000ha plantation	98,3	104,8	111,5	117,6	123,9	130,4	137,0	143,8	150,9	158,1	165,6	173,2	181,1
A) <u>New Sources</u>													
Charcoal													
Haut Mangoro Pine	0,0	0,0	0,0	18,7	18,7	18,7	18,7	18,7	18,7	18,7	18,7	18,7	18,7
Logging Residues	0,0	0,0	0,0	0,0	32,3	43,0	57,3	76,5	102,0	136,0	181,3	241,8	322,5
Sawmill Wastes	0,0	0,0	0,0	0,0	2,1	2,7	3,7	4,9	6,5	8,7	11,5	15,4	20,5
Lac Aloatra Charcoal Briquettes	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,3	3,9	6,6	11,2	19,0	22,8
Total Charcoal	0,0	0,0	0,0	18,7	53,0	64,5	79,7	102,4	131,1	170,0	222,8	295,0	384,6
Agricultural Residues Rice Husk Briquettes	0,0	0,0	0,0	0,0	3,5	4,7	6,3	8,3	11,1	14,8	19,8	26,4	35,2
Sub-Total A)	0,0	0,0	0,0	18,7	53,0	64,5	79,7	102,4	131,1	170,0	222,8	295,0	384,6
B) <u>Upgraded Production</u>													
Traditional Charcoal	0,0	0,0	0,0	10,8	21,7	32,5	43,3	54,2	65,0	75,8	86,6	97,5	108,3
Copice Management	0,0	0,0	0,0	0,0	3,2	4,3	5,8	7,7	10,2	13,7	18,2	24,3	32,4
Sub-Total B)	0,0	0,0	0,0	10,8	24,9	36,8	49,1	61,8	75,2	89,5	104,9	121,8	140,7
C) <u>Expanded Modern Fuel Supply</u>													
Kerosene	0,0	0,0	0,0	0,0	8,9	11,9	15,8	21,1	28,1	37,5	50,0	66,7	89,0
Electricity	0,0	0,0	0,0	0,0	-	11,0	15,5	21,7	30,3	42,4	59,4	83,2	110,5
Sub-Total C)	0,0	0,0	0,0	0,0	8,9	22,9	31,3	42,8	58,5	80,0	109,5	149,9	199,5
Total Supply	931,4	931,5	932,0	962,2	1,024,0	1,064,0	1,103,4	1,154,7	1,218,1	1,299,8	1,406,2	1,546,7	1,718,4
Deficit	1,180,0	1,257,9	1,338,4	1,382,1	1,396,6	1,435,5	1,477,7	1,510,8	1,534,5	1,543,0	1,529,7	1,485,6	1,413,5

<u>Source</u>: Mission Estimates.

Annex 4

STATISTICS ON PLANTATIONS BY PROVINCE
('000 ha)

Province	< 1965	1966-70	1971-75	1976-80	> 1980	Total
Antananarivo	29.8	10.4	8.4	3.2	1.0	52.8
Fianarantsoa	13.8	16.2	2.0	0.6	0.3	32.9
Toamasina	6.2	9.3	1.2	1.4	0.1	18.2
Mahajanga	2.5	1.6	1.2	0.4	0.1	5.8
Toliary	5.0	2.7	0.6	0.6	0.1	9.0
Antsiranana	1.3	2.2	0.5	0.2	0.1	4.3
Total	58.6	42.4	13.9	6.4	1.7	123.0

Source: Computed from seedlings statistics of Eaux et Forets, with an average number of 2,000 seedlings per hectare, and a failure ratio of 20%.

Note: The plantations established by the Department des Eaux et Forets average half of the above, the rest being supplied by local communities and individuals. It should be noted that the totals above are notably inferior to the figures quoted by Rakotomananpison in Situation Forestiere a Madagascar (Direction des Eaux et Forets - MPAEF - June 1984) (roughly half). The latter author recognizes a much higher share of State plantations.

Annex 5

ECONOMICS OF CHARCOAL-MAKING WITH TRADITIONAL KILN - ABOVE-GROUND EARTH OR EARTH CLOD - 16 stere (e.g. 4.3 x 3.7 x 1.0 av.)

A. Costs

1. Equipment

	Costs per stere USc	Costs per stere FMG	Costs per stere USc	Costs per stere FMG
- Tolls (machet, axes, spades) $25/man x 4 men = $100 with life of 3 years; 0.4021 c.r.f.	5.0	31.4	1.29	806
- Parts and maintenance (20%)	1.0	6.3	0.26	161

2. Labor Costs (per 16 stere kiln)
   - 4 men manage 2 kilns
   - cycle is about 14 days
   - 16 mandays/kiln, as follows (md):

— cutting, marking & carrying	8
— preparing and loading	2
— unloading and bagging	2
— attending kiln	4
	16

i.e. 2 st/md cutting etc., 1 st/md overall, and 200 days/man/year; 800 md/yr, 25.6 md/t and 25.6 steres/t charcoal.

	USc	FMG	USc	FMG
3. Bags/string at 150 FMG/bag (used 3 x)	11.6	72.2	2.96	1852
4. Resource cost: negotiated harvesting fee taken as FMG 30,000/ha of 100 m^3 or 300 FMG/m^3	31.2	195.0	8.00	5000
TOTAL	48.8	304.9	12.51	7819

B. Benefits

5. Production: 800 steres x 0.65 (reducing factor to solid volume) x 0.4 (400 kg/m^3 bd) x 0.15 (efficiency of conversion) = 31.2t charcoal and 39 kg charcoal/stere.
   Selling Price: FMG 30/kg
   Revenue: 31.2t x 30,000 FMG/t = 936,000 FMG

C. Returns

	US$	FMG
6. Gross - per manday and stere	1.87	1170
7. Net - per manday and stere	1.38	863

Annex 6

ECONOMICS OF CHARCOAL-MAKING WITH IMPROVED KILN
- 16 STERE KILN, 7 DAY CYCLE
(800 steres, or 208 odt, processed per year for 41.6 t charcoal per year)

A. Costs		Costs per stere USc	Costs per stere FMG	Costs per stere USc	Costs per stere FMG
1. Equipment					
Tools - first cost		5.0	31.4	0.96	604
- parts, maintenance		1.0	6.3	0.19	121
Kiln metal parts					
- Chimneys (1 or 2) 2.5 m					
- Ventilation pipes (3-4) 1 m					
- Life 2 years					
Total cost about $200, c.r.f. = 0.5762, thus annual cost is $115.24		14.4	90.0	2.77	1731
2. Labor Costs (per 16 stere kiln, 7 day cycle) (md)					
- cutting, stocking, carrying	8				
- preparing kiln, loading	2				
- attending kiln	2				
- unloading and bagging	2				
	14				
i.e. 0.88 md/stove and 704 md/yr overall, thus 14.8 md/t charcoal and 19.23 steres/t charcoal					
3. Bags/string at FMG 150/bag (used 3 x)		15.4	96.3	2.96	1852
4. Resource cost: FMG 300/m^3		31.2	195.0	6.00	3750
TOTAL		67.0	419.0	12.88	8058

B. Benefits

5. Production: 16 steres = 4.2 odt
   - 20% efficiency yields, 840 kg/kiln
   - 800 steres yield 41.6 t/yr charcoal and 52 kg charcoal per stere

Revenue: 41.6t x 30,000 FMG/t = 1,248,000 FMG

C. Returns

		US$	FMG
6. Gross	per man day	2.84	1773
	per stere	2.50	1560
7. Net	per stere	1.83	1144
	per man day	2.08	1300

CARBONISATION AS AN ALTERNATIVE TO PELLETISATION OF FANALAMANGA'S PINE SMALLWOOD AND PINES THINNINGS RESOURCE

Background Notes: Two types of resources could be recovered at FANALAMANGA for woodfuels production:

-- clearfelling the "pins mal venants" before replacing;

-- processing of thinnings from regular maintenance of existing plantations.

The estimates of the quantities involved for each class of residue need to be carefully assessed, but here the Sandwell estimate of 191,000 m^3/year is adopted for analysis. Charcoal production is assumed to be with "Ghana" type metal kilns at + 21,500 tonnes/year, of which 15,900 t/y would be committed to CIMA and 5,600 t/y to household use. The latter represents less than 10% of the present Antananarivo faritany's consumption. Given the rapid increase in consumption, the market for the charcoal produced should not be a problem, if marketing and transportation are adequately designed and implemented.

The assumptions made for analyzing the project are as follows:

-- Density of pine wood is 450 kg/m^3 (higher than normal due to slow growth.
-- "Ghana" type kiln has 6.5 stere capacity (or 4.23 m^3 or 1.9 t od).
-- Kiln efficiency is 25%, hence [illegible] kg of charcoal are produced per firing.
-- Kiln is fired 80 times/year, hence 152 t/y of od wood produce 38 t/y of charcoal.
-- Kiln cost is US$800 plus transportation to Moramanga, life is 5 years.
-- Kilns are managed in units of four by four workers full time.
-- Material flow is 1 stere/md.
-- Each kiln carbonizes 340 m^3/y, hence 556 kilns are required during the first five years of operation (plus 20% contingency in actual operation for spare kilns and spare parts), and 139 teams are required.
-- Wages will be piece rate, but will average 40,000 FMG/month (US$64/month) for 200 days of work/year.
-- Tools will include bow saws, machettes, forks, gloves, spades, or US$50/year/man on the first year, replacement of half of it after two years the total replacement after four years.
-- Tractors, transport of kilns, charcoal and miscellaneous - US$9.4/t.
-- The price of charcoal is 30 FMG/kg at Moramanga for household quality charcoal and 96.52 FMG/kg for charcoal destined for use by GMA. Details of the cash flow analysis are provided below in tabular form.

COMPARATIVE ECONOMIC ANALYSIS OF CARBONISATION AND PELLETISATION OF STUNTED PINES AND PINE THINNINGS
Haut Mangoro Plantation

Cash Flow Analysis
(1,000 US$)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Kilns Purchase	452,0																			
Kilns Replacement				452,0			452,0			452,0			452,0			452,0				
Tractors/Trailers	330,0							330,0							330,0	330,0				
Tools	28,2		14,1		28,2		14,1		28,2		14,1		28,2		14,1		28,2		14,1	
Other Capital	200,0										200,0									
Contingencies	101,0	0,0	1,4	45,2	2,8	0,0	46,6	33,0	2,8	45,2	21,4	0,0	48,0	0,0	34,4	78,2	2,8	0,0	1,4	0,0
Total Capital	1,111,2	0,0	15,5	497,2	31,0	0,0	512,7	363,0	31,0	497,2	235,5	0,0	528,2	0,0	378,5	860,2	31,0	0,0	15,5	0,0
Labor	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2	433,2
Tractors Operation	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0	154,0
Other Running Cost	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9	257,9
Total Running	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0
Sale of Charcoal	0,0	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8	2,723,8
Net Cash-Flow	-1,956,2	1,878,8	1,863,3	1,381,6	1,847,7	1,878,8	1,366,1	1,515,8	1,847,7	1,381,6	1,643,3	1,878,8	1,350,5	1,878,8	1,500,3	1,018,6	1,847,7	1,878,8	1,863,3	1,878,8

	Million $	Billion FMG		
Net Present Value	11,0	6,9	Proxy for analysis	1,0
Discount Rate	10,0 %		Rate of Return	91,7 %

Direct Comparison of Capital Outlay and Cash Flows: Local Charcoalers vs Sandwell Project
('000US$)

Carbonisation from local Charcoalers

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Total Capital .	1,111,2	0,0	15,5	497,2	31,0	0,0	512,7	363,0	31,0	497,2	235,5	0,0	528,2	0,0	378,5	860,2	31,0	0,0	15,5	0,0
Total Running	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0	845,0
Sale of Charcoal	1,031,4	0,0	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5	2,805,5
Net Cash-Flow	-1,956,2	1,878,8	1,863,3	1,381,6	1,847,7	1,878,8	1,366,1	1,515,8	1,847,7	1,381,6	1,643,3	1,878,8	1,350,5	1,878,8	1,500,3	1,018,6	1,847,7	1,878,8	1,863,3	1,878,8

Pelletisation cum carbonisation (from Sandwell Co, Project Analysis)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Total Capital	560,0	6,500,0	1,383,0	230,6	194,6	295,2	329,2	365,0	496,2	451,7	111,6	20,0	344,3	120,0	80,0	80,0	80,0	80,0	80,0	-327,0
Total Variable	0,0	0,0	1,178,5	1,341,0	1,368,7	1,424,0	1,506,8	1,534,4	1,562,1	1,617,4	1,589,7	1,396,5	1,341,0	1,341,0	1,424,0	1,341,0	1,341,0	1,341,0	1,341,0	
Total Fixed	0,0	0,0	200,3	200,3	200,3	200,3	200,3	200,3	200,3	200,3	200,3	200,3	200,3	200,3	200,3	200,3	200,3	200,3	200,3	
Sales of Pellets	0,0	0,0	609,2	807,2	807,2	807,2	807,2	807,2	807,2	807,2	807,2	807,2	807,2	807,2	807,2	807,2	807,2	807,2	807,2	
Sales of Charcoal	0,0	0,0	1,360,3	2,181,4	2,181,4	2,181,4	2,181,4	2,181,4	2,181,4	2,181,4	2,181,4	2,181,4	2,181,4	2,181,4	2,181,4	2,181,4	2,181,4	2,181,4	2,181,4	
Net Cash-Flow	-560,0	-6,500,0	-772,5	1,216,8	1,225,1	1,069,2	952,4	914,3	865,5	674,8	747,0	1,280,5	1,427,4	1,105,1	1,244,4	1,367,4	1,367,4	1,367,4	1,367,4	327,0

Net Present Value	0,0 million dollars	Rate of Return	10,1 %
Discount Rate	10,0 %	Proxy for analysis	0,1

Carbonization Project Parameters

Pine Density	kg/m3	450,00	Productivity	stere/md	1,00	Coal Price	26,44 FMG/kg	Pellets	50,77 FMG/kg	Indicators	Local CC	SANDWELL
Kiln Capacity	stere	6,50	Monthly Wag.	1,000 FMGs	40,00	Ocean Freight	10,59 FMG/kg	CC Price	96,52 FMG/kg	DNCF M $ 10%	11,0	,0
Efficiency	%	25,00	Contingency	%	10,00	Insurance	0,27 FMG/kg			IRR %	91,7	10,1
Kiln Cycles/year	no.	80,00	Tools	$/man/y	50,00	Unloading	10,08 FMG/kg			Capital (M US$)	1,15	8,44
Kiln Cost (delivered)	US$	800,00	Transport	$/t	9,40	Port Charges	0,25 FMG/kg			Labour (m/year)	564,00	437,00
Life Kiln	years	5,00	Tractor	'000US$	50,00	Port Storage	0,24 FMG/kg					
Rate Exchange	FMG/$	625,00	Volume Cut	'000 m3/y	191,00	Inland Transport	50,88 FMG/kg					
Discount Rate	%	10,00	after 5 y	'000 m3/y	191,00	Del. Coal Cost	98,12 FMG/kg					
Cap. Recovery	as dim	0,26	Price CC ...	FMG/kg	50,00	Thermal Efficiency Factor	1,25					
			Price CC CIMA	FMG/kg	96,52	Delivered CC price	123,40 FMG/kg					
Number of Kilns	number	565,00	Tractors	number	11,00	Rail Freight	26,88 FMG/kg					
Teams	number	141,00	Tracto Cost	'000$/y	14,00	Mill Net CC Price	96,52 FMG/kg					
Kiln Cost	'000 US$	497,20	Stores/Houses	'000 US$	200,00							
Tools cost	'000 US$	28,20	Other Costs	FMG/kg	7,50	Rail Rate	48,00 FMG/TK					
Tractors Cost	'000 US$	350,00	CC Production	t/y	21,487,50	Rate Inc. CC	1,00					
Capital Cost	'000 US$	855,40	CIMA Consumption	t/y	15,900,00	Moramanga-Toamasina	250,00 km					
Labor Cost	'000 US$/y	433,15				Moramanga-Antsirabe	280,00 km					

Note: Tools are totally replaced every four year, and half of it is replaced every second year.
The normal rail rate is given hereabove, it is increased by a factor (presently 100%) to take into account the low density of CC vs Coal.

Source: Mission estimates.

Annex 8

ESTIMATED CROP RESIDUES PRODUCTION FOR SELECTED CROPS, 1984
('000 tonnes/year)

Product	Production Main Product	Field Residues	Industrial Residues	Total
Grains				
Paddy rice	2,132	4,050	533	4,583
Maize	141	423	0	423
Sorghum	1.5	3.0	0	3
Legumes				
Beans	41	NKP	0	-
Roots and Tubers				
Potatoes	263	53	0	53
Cassava	2,047	410	0	410
Sweet potato	462	92	0	92
Taro	93	19	0	19
Industrial Crops				
Sugarcane	1,660	xxx	1,210	260 a/
Groundnuts	31	NKP	NA	-
Cotton	30	150	NKP	150
Coffee	81	0	33	33
Cocoa	2	0	1	1
Pepper	3	NKP	NKP	-
Vanilla	5	NKP	NKP	-
Clover	13	NKP	NKP	-
Sisal	20	NKP	15	15

NA: Quantities not assessed.
KP: Known potential.
NKP: No known potential.

a/ Maximum potential surplus and bagasse and cane field residues (oven dry).

STATISTICS ON ANTANANARIVO RICE MILLS

Rice Mill	Location	Year of Commissioning	Capacity tonnes/hr a/	Annual throughput of paddy	Annual production of husk
1. RICE MILLERS UNION					
Andriamanobola Gabriel	Isotry	1960	1		
Ramanandraibe	Isotry		1.1		
			1.3		
Ramanandraibe	Mahitsy		2		
Rakotondratafika	Ambatolampy	1964	2		
Rajaofera Fredy	Anosizato Ouest	1969	1.8		
Moolamahefa	Antanimena		2		
Ramanamefa	Ambodihady		1.5		
Ravonjiarivelo	Ambohimanambola	1980	2		
Rasoanoro	Antsahadinta		1		
Ranaivo Norbert	Andranobevava		1		
Ramahandry Victor	Ambohibao		1		
Randriambolonda Justin	Ambohibary		1.5		
Ramahandry	Andavabato		2		
Loenan'imamo	Arivonomano		1.8		
Andriamiadana Samuel	Fenoarivo		2		
Rasoloarijao	Fihaonana		1.8		
Rasoanaivo	Tsiroanomandidy		2		
Subtotal (17 mills)			28.8	34,560	7,260
2. SOPIMA					
Rakotonarivo	Antohomadinika	1956	2		
Rabehaja	Andohatapenaka	1964	1		
Razakamanana	Tsiazotafo	1972	2		
Rabejaha Vincent	Anosizato Ouest	1979	3		
Rakotozanany Augustin	Antsirabe	1958	3		
	Betafo	1953	1		
Rakotoniaina Georges	Antsirabe	1964	2		
Razafimandranto	Ambohimanarina (digue)	1964	1.5		
Razafimahatana	Ambohitrimanjaka	1964	1		
Rakotondrabiby	Imeritsiatosika	1964	2		
Rze. of Imeritsiatosika	Imeritsiatosika	1964	1.2		
Ramanantseheno	Imeritsiatosika	1953	1		
Rakotoralahy	Imeritsiatosika	1953	1		
Rie. ny Antsika	Betafo	1957	3		
Razafindrazaka	Imeritsiatosika	1954	1		
Razafindrangodona	Ambod itsiry	1954	1		
Heritier Rabehaja	Isotry	1964	1		
Subtotal (17 mills)		30.7	36,840	7,740	
3. NATIONALIZED MILLS					
SINPA	Ansirabe		3		
	Miarinarivo		3		
ROSO	Andrefan'Amboijanahary		1		
Subtotal (4 mills)		9	10,800	2,270	
TOTAL (38 mills)		68.5	82,200	17,270	

a/ Hourly capacity x 1,200

Background Notes

1. There are a total of 38 rice mills operating in Antananarivo faritany, as listed in the table. As can be seen, the mills have capacities ranging from 1 to 3 tons of paddy rice/hour. They all produce husk as a by-product of the milling operation and this husk is by and large a nuisance.

2. Only a couple of millers presently burn part of the husk in appropriate boilers. For the rest of the husk, and for the vast majority of millers, husk has to be disposed of. A part of it is collected by local farmers who use it for bedding or feeding to animals, but not in large quantities. The result is that millers have to spend money and energy to get trucks to haul the husk to a minimum distance of 5 km (given the urban environment), with several trips per day (up to 18 trips in one place visited by the mission).

3. Millers are keenly interested in any possibility for disposing of the husk economically. The total resource has been estimated with the following assumptions:

   — mills operate 20 h/day 6 days/week and 9 months/year;
   — husk is 21% of the paddy rice processed.

   Under these conditions, the total resource would exceed 17,000 tonnes husk/year.

4. In Antananarivo faritany, the most sensible solution for processing the husk would be to produce rice husk fuel briquettes for household or industry for local consumption.

Annex 10

ESTIMATED COST OF PRODUCTION OF RICE HUSK BRIQUETTES, ANTANANARIVO, 1984

Capital cost of briquetting press landed in Antananarivo: US$25,000 plus 20% installation, including conveying and civil works.

Capacity of briquetting press, 300 kg/hr continuous.

Labor requirements: two installed per 8 hour shift or FMG 960,000/year.

Operating characteristics of machine: 8 hors/day, 6 days per week, 50 weeks per year, with 10% forced outage. Hence annual hours of operation are 2,160 and annual production is 648 tonnes of briquettes.

Life of briquetting press is 20 years, capital recovery of US$3,525/year at 10% discount rate.

Maintenance including skilled labor, grease and oil and parts is 5% of capital cost (c.i.f.) or US$1,250 per year.

Energy demand is 20 kWh/tonne of briquettes produced at estimated cost of 50 FMG/kWh or US$.08/kWh, hence US$1.60 or 1,000 FMG/tonne.

No credit is made for savings through not removing husks, whereas the cost is approximately 1,000 FMG per tonne.

Cost of Production a/
(US$ and FMG thousands)

			--per tonne--	
	US$	FMG	US$	FMG
Capital charges	3,525	2,203	5.44	3.40
Maintenance	1,250	781	1.93	1.21
Labor	1,536	960	2.37	1.48
Power	1,036	648	1.60	1.00
Total	7,347	4,592	11.34	7.09

Production cost per kg to factory gate: 1.1 cents or 7.1 FMG

a/ Exchange rate: US$1.00 = FMG 625

DRAFT TERMS OF REFERENCE FOR INTEGRATED ENERGY AND AGRICULTURE PLANNING STUDY FOR THE LAC ALOATRA REGION

Local Vehicle for the Study

1. The Lac Aloatra Regional Energy Planning Study (LAREP) will be undertaken by a multidisciplinary team of energy specialists, agriculturists and foresters who would work in close cooperation with the regional Research and Development Committee comprising local representatives of MPARA, MPAEF and FOFIFA, and representatives from SOMALAC. The committee would be responsible locally for supervising and facilitating the study.

Team Composition

2. The team will include at least the following specialists on full or part-time basis:

- Team leader with extensive experience in energy planning and management, preferably with experience of similar regional planning activities and preferably with a background in economics and agriculture or engineering and fluency in French.
- Power Engineer (hydro and transmission-distribution).
- Engineer specialized in rice factory engineering and process energy management, and biomass combustion systems.
- Biomass Energy Specialist.
- Forester-Ecologist with extensive knowledge of soil conservation practices and community/agro-forestry.
- Hydrological Engineer/Hydrologist.
- Sociologist/Human Ecologist.
- Agronomist with some knowledge of livestock.
- Agricultural Economist or Natural Resource Economist with experience in land use planning.

3. The precise scope of work and individual terms of reference for LAREP should be an outcome of a brief preparatory field mission comprised of two or three generalists with relevant experience working in close liaison with the GOM, Bank, Caisse Centrale and Lac Aloatra regional agencies. This mission would prepare a detailed budget, work plan and implementation schedule for the planning and pre-investment study, specifying anticipated outcomes in terms of general policy and strategic issues to be resolved or reviewed, known projects to be examined and investment programs and strategic planning to be completed.

4. Preparation for the study will involve at a minimum:

-- Reaching agreement on the timeframe for the study.

-- Delineation of the geographical area under study. For example, it may be desirable to include the summer grazing grounds in the study area (grazing grounds 40 km north-west of the Lake).

-- Compilation and analysis of available data of relevance to the study.

-- Description of present energy supply-demand patterns, both traditional and modern forms, by fuel and major economic end-use. This will require identifying the main social categories consuming/producing energy in the area (rice millers, agencies and associated settlemts, farmers outside and inside SOMALAC areas, transporters, etc.); identifying energy consumption by each major economic activity and by energy form (petroleum products, electricity, rice husk, etc.), and end-use (e.g. household cooking, water heating and steam raising, fixed motive power, transport, farm machinery, lighting, etc.) for the base year, and compilation of a reference regional energy balance.

5. The study will include:

-- Resource inventories and assessments of the economic costs of present and prospective energy sources.

-- Determination of feasible regional development scenarios as a basis for defining energy needs and the demand for other natural resources such as forests, land and water.

-- Identification of related policy and planning issues and energy and resource development and management programs and projects within an agreed framework for regional economic development.

-- Identifying suitable institutional arrangements and manpower development and training issues and options.

-- Preparation of investment programs in accordance with least-cost solutions for energy supply and other resource development and management requirements.

Anticipated Energy and Other Resource Management & Development Issues

Electrification:

Options for regional electrification including interconnection with the JIRAMA grid; local hydropower development (3.5 MW potential identified at outlet of Lac Aloatra); rice husk/straw-fired steam power production.

Design and costing of options for transmission and distribution systems.

Utilization of Rice Crop Residues:

Analysis of economics of collection and processing of rice straw and rice husks for production of household and industrial fuels for local or external use vis-a-vis agricultural consumption of some of this resource.

Afforestation:

Review of present forest cover and potential utilization. Analysis of need for afforestation both on-farm and protection forestry and industrial and fuelwood plantations/wood lots. Design of infrastructure requirements for rural and plantation forestry and specification of location and land area suitable for forest development.

Irrigation Systems:

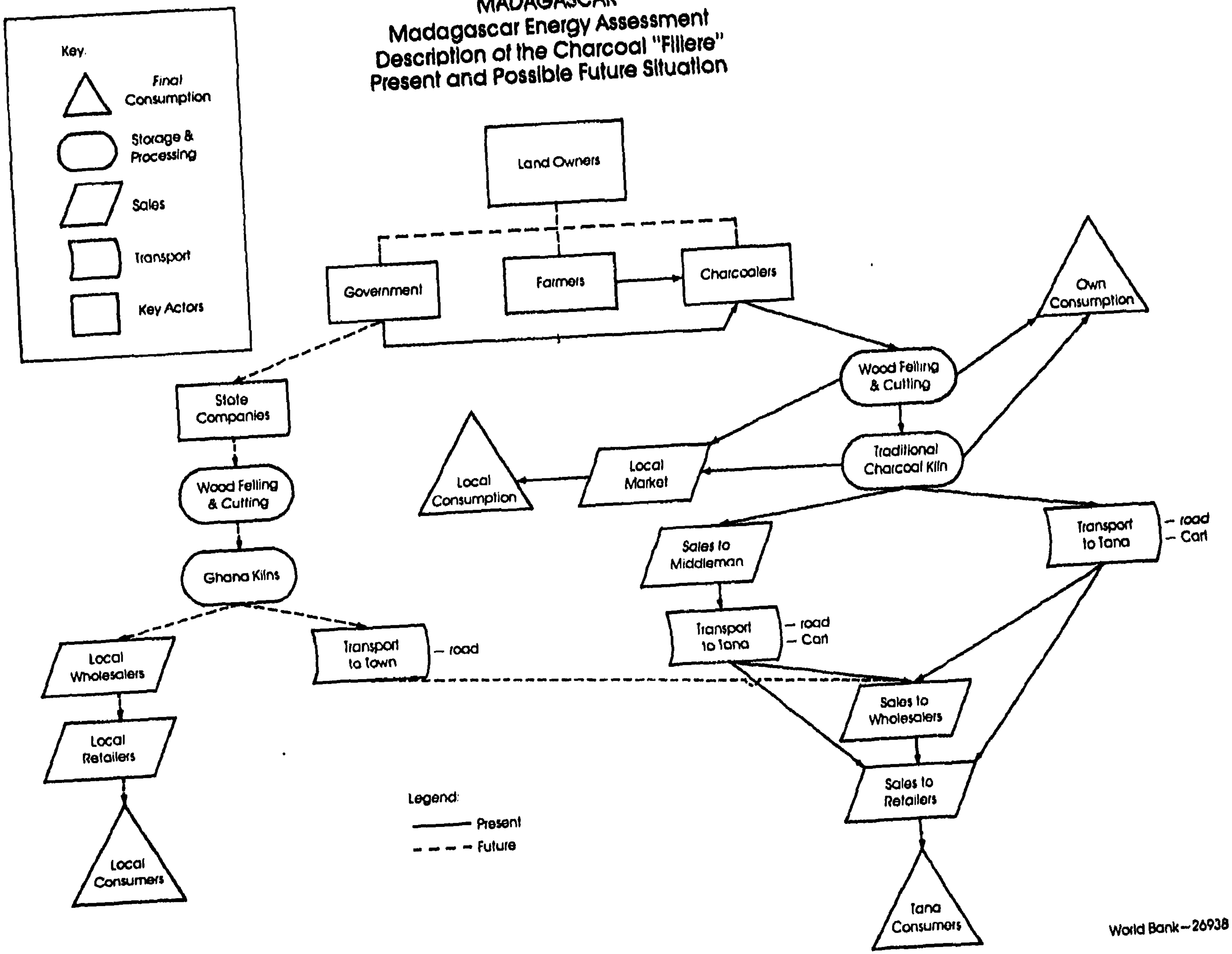
Both water management for irrigation and water supply generally and analysis of least-cost practical means of supplying energy for non-gravity fed irrigation systems.

HOUSEHOLD SUB-SECTOR INVESTMENT PROGRAM
1986 - 1995 ('000US$)

Investment Category	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total
Carbonisation Programs											
Haut Mangoro Pine Waste	1,111		16	497	31		513	363	31	497	3,059
Logging Residues		51	17	23	81	57	77	204	170	227	907
Sawmill Residues		14	5	6	8	11	28	24	32	42	170
Lac Alaotra Rice Husk Briquettes					144	48	82	162	244	415	1,095
Upgrading Traditional Charcoaling	8	8	16	16	23	23	31	31	39	39	234
Sub-Total	1,119	73	54	542	287	139	731	784	516	1,220	5,465
Forestry Programs											
Fuelwood Plantations											
Plantation Established ('000ha)		1.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	14,000ha
Investment Required ('000US$)	750	1,875	2,250	2,250	2,250	2,250	2,250	2,250	2,625	3,000	21,750
Rural Aforestation											
Plantation Equivalent ('000ha)		1	2	3	3	3	3	3	4	5	27,000ha
Investment Required ('000US$)	150	450	750	900	900	900	900	1,050	1,350	1,500	8,850
Coppice Management Improvement	—	100	200	200	200	100	100	100	100	100	1,200
Sub-Total	900	2,425	3,200	3,350	3,350	3,250	3,250	3,400	4,075	4,600	31,800
Cooking Electrification											
Number of Houses		0	0	503	704	986	1,380	1,932	2,705	3,787	11,997
Investment Required		0	0	578	810	1,134	1,587	2,222	3,111	4,355	13,797
Rice Husk Briquetting: Antananarivo											
Briquette Capacity ('000t/y added)		2	1	1	1	1	2	2	3	4	16
Required Investment		98	33	43	58	77	103	137	183	244	976
Technical Assistance and Studies											
Carbonisation Training	200	100	100	100	100	100	100	100	100	100	1,100
Resource Inventory Work	500	500	500	500	500						2,500
Rice Husk Briquetting	50										50
Cooking Efficiency Programs	530	500	500	500	500						2,530
Cooking Fuel Demand Surveys	120	100	100								320
Cooking Electrification Review	50										50
Lac Aloatra Energy Dept. Plan	280	250	—	—	—	—	—	—	—	—	530
Sub-Total	1,730	1,450	1,200	1,100	1,100	100	100	100	100	100	7,080
Manpower Training and Development	130	100	100	100	100	100	100	100	100	100	1,030
Total	3,879	4,146	4,587	5,713	5,705	4,800	5,871	6,743	8,085	10,619	60,148

Source: Mission estimates.

MADAGASCAR
Madagascar Energy Assessment
Description of the Charcoal "Filiere"
Present and Possible Future Situation



World Bank—26938

Annex 14

PARAMETERS FOR ECONOMIC ANALYSIS OF POWER PRODUCTION FROM RICE HUSK, LAC ALOATRA, MADAGASCAR, 1984

Rice Husk Resource

Daily rice production	470.00	t/day
Number of rice mills	9.00	
Installed power	1341.00	kVA
Present power generation	5021.00	MWh/year
Discount rate	0.10	
Amortization period	25.00	

Rice husk production	155.10	t/day
	36290.00	t/year
Total power production	21774.00	MWh/year
Required capacity	5816.00	kW
Required investment	4650.00	(1,000 US$)
Cost of electricity	0.03	US$/kWh
	21.38	FMG/kWh

Annex 15

POTENTIAL OF BAGASSE FOR POWER GENERATION, 1984

Nosy Be Sugar Factory Study

1. The sugar factory studied, known as Dzamandzar, crushed an average of 137,500 tonnes of cane/year, producing 15,000 t/y of sugar during the period 1977 through 1983. The average fiber content in the cane was 15.5%, and the average moisture content of bagasse was 50.2%. Assuming a unit consumption of 22 kWh/tonne of cane crushed, and a new boiler efficiency of 84%, the potential power generation surplus is estimated at between 6.4 and 9.7 GWh/year. The power consumption of Nosy Be island is 5.2 GWh/year with a peak demand of 1,260 kWe. The cost of power to the consumer is between 40 and 61 FMG/kWh, with an average of 48 FMG/kWh, of which a minimum of 43.4 FMG/kWh is the cost of diesel fuel alone. The study recommends that the generation period be extended from the present 4-6 months to 9 months, and thus provide 3.9 GWh to the small island during that period, the existing diesel generator providing power during the remaining trimester. The cost of the additional equipment required to generate a surplus of power is estimated at US$2.2 million for an installed power output of 4.4 MWe, at 500 US$/kW installed. The cost of the electricity produced is estimated at 31.4 FMG/kWh (about 0.05 US$/kWh), including 23.9 FMG/kWh for depreciation of the equipment. Thus, bagasse power generation would be markedly more cost-effective than diesel generation.

Potential of National Industry

2. Overall bagasse production in Madagascar gives rise to a "surplus" which can be used for power generation, once the appropriate boilers will have been installed. To estimate this potential, two assumptions can be made: average production (4% of bagasse available) and above average availability in Madagascar (5.8% of bagasse available, as in of Nose Be). Considering only the global rather than Nose Be fiber content data available, bagasse will be 29,000 to 42,000 tonnes/year. This quantity would permit the production of 19 to 28 GWh/year, and would substitute 4,800 to 7,000 toe/year in diesel power generation equivalent. Ironically, the problem may be a lack of demand on local public supply networks. Taking an average figure of 650 kWh/household/y for lighting and appliances other than electric cooking, there would need to be 30,000 to 43,000 subscribers for prospective surplus bagasse power to be fully utilized, or a population of 177,000 to 257,000 people. This figure is likely to exceed that within economic transmission distance from the respective supply sources. Nevertheless, not all of the power potential need be exploited immediately, and further study should examine the economics of supplying the existing market and expanding the supply in increments to meet anticipated demand growth. The actual national potential will be assessed by the large sugar study commissioned for the spring 1985 by the CCCE, which aims at rehabilitating the sugar industry. That mission will include an energy specialist to more closely define bagasse power potential.

Annex 16

ECONOMIC ANALYSIS OF ETHANOL PROJECTS:
PROJECTED PROFIT AND LOSS ACCOUNT

	1987	1988	1989 & beyond
Physical Data			
Ethanol (ML)	1.50	2.55	3.00
Revenue			
Ethanol ('000 US$)	330.00	561.00	660.00
Operating Costs			
Molasses	206.90	351.72	413.79
Salaries and Wages	140.00	140.00	140.00
Maintenance			
Plant	60.00	60.00	60.00
Buildings	12.00	12.00	12.00
Chemicals	15.00	25.50	30.00
Utilities	37.34	63.49	74.69
Total	471.24	652.71	730.48
Operating Profit (before amortization, depreciation, interest,and tax)	-141.24	-91.71	-70.48
Operating Loss ¢ per litre	-9.42	-3.60	-2.35

Assumptions:

Production of ethanol starts in third year, 1987 at 50%, fourth year at 85% and fith and later year at 100%. Factory gate price for ethanol is US¢22.00 which is derived from the c.i.f value of gasoline less 1.00 ¢ for blending costs.

Raw material costs consist of the following: (a) US¢1.00 per litre for chemicals; (b) US$40.00 per tonne of molasses, assuming a yield of 290 litres of ethanol per tonne. This results in cost of US$13.79 per litre.

Salaries per annum for the skilled and unskilled labour are estimated respectively at US$100,000 and US$40,000.

Maintenance of plant and buildings is assumed to be 3% of capital cost. Capital cost of plant and buildings is estimated respectively at US$200,000 and US$40,000. The resultant annual maintenance cost is US$60,000 for the equipment and US$12,000 for the buildings.

Utilities comprise power, steam, and water. The total utilities cost is estimated at US¢2.49 per litre of ethanol produced. This is derived as follows:

(a) power input is assumed to be 0.11 KWh per litre at marginal cost of US¢5 per KWh. Thus, power cost per litre is US¢0.55 (i.e., 0.11 times 5.00);

(b) steam input is assumed to be 4 Kg per litre of ethanol at 15 psi. Assuming further 2.7 mJ/Kg steam and 65% boiler efficiency with fuel as baled bagasse at 25% moisture. Thus the energy requirements are 4.15 mJ/Kg steam or 16.62 mJ/litre ethanol. If the cost per tonne for bagasse dried and baled is US$10.00, and an energy value of 13.30 mJ/Kg, the cost per litre of ethanol is about US¢1.25;

(c) water input comprise of both cooling water and process water. Process water requirements are estimated at about 40 m^3 per day. Costs of pumping, water treatment, and storage are estimated at US$0.15 per litre of ethanol. Cooling water requirements are estimated at 1,000 m^3 per day with costs associated with pumping estimated at US¢5 per m^3 or approximately US¢0.50 per litre.

Annex 17

ECONOMIC ANALYSIS OF BIOGAS PRODUCTION, MADAGASCAR, 1984

A: "normal conditions" with Antsahasoa example

Parameters

	1,000 FMG	US$		
			Life of digestor	10
			Discount Rate	10
Total investment	3000.0	4800.0	Exchange Rate	625.0
			Digestor Volume	20.0
			Gas Production	5.0 m^3 daily
Depreciation	488.2	781.2		
Operations and Maintenance	600.0	960.0	% Methane	60.0
			% Organic Matter	20.0
Total annual cost	1088.2 FMG/y	1741.2 US$/y	Energy in Methane	0.9 kgoe/m3
Market value of Energy	170.1 FMG/y	272.2 US$/y		
Energy production	810.0 koe/year		Market price of kgoe	210.0 KMG/kg
Cost/kilogram oil equivalent	1344.0 FMG/koe	2.15 US$/koe		

B: "existing conditions" with Antsahasoa example

Parameters

	1,000 FMG	US$		
			Life of digestor	10
			Discount Rate	10
Total investment	3000.0	4800.0	Exchange Rate	625.0
			Digestor Volume	20.0
			Gas Production	5.0 m^3 daily
Depreciation	488.2	781.2		
Operations and Maintenance	150.0	240.0	% Methane	60.0
			% Organic Matter	5.0
Total annual cost	638.2 FMG/y	1021.2 US$/y	Energy in Methane	0.9 kgoe/m^3
Market value of Energy	170.1 FMG/y	272.2 US$/y		
Energy production	810.0 koe/year		Market price of kgoe	210.0 KMG/kg
Cost/kilogram oil equivalent	788.0 FMG/koe	1.26 US$/koe		

Annex 18

SUMMARY OF RECENT HYDROPOWER RESOURCE INVENTORIES

1. Several resource inventory and detailed design studies of small-scale hydropower have been conducted in recent years. Samples of the work completed are as follows:

CI Power Services, October 1982, identified from eight shortlisted sites the following four projects for development, namely:

Location	Power Output	Faritany
Andapa	4.4	Antsiranana
Manatsimba	5.0	Fianarantsoa
Maroantsetra	4.0	Toamasina
Lac Aloatra	3.5	Antananarivo
TOTAL	16.9	

2. A 1975 inventory produced by the Service de l'Energie of the then Ministere de l'Economie et du Commerce listed 99 potential sites of varying importance for a total of 4221 MWe and 25,210 GWh/year of production (however, the power output figures were not fully comparable, and thus should not have been added). A more recent inventory by JIRAMA yielded the following:

Unit of Power Output	No. of Sites	Power Output (MWe)	Production (GWh/y)
Above 50 MWe	33	6,330.0	55,704.0
5 to 50 MWe	21	194.0	1,707.0
1 to 5 MWe	72	167.8	1,475.2
.1 to 1 MWe	159	59.8	526.4
Below .1 MWe	54	3.2	28.5
TOTAL	339	7,054.8	59,441.1

Note: In the definition of JIRAMA, the power output is the average year-round power output, and not the installed power, which is substantially higher (by two or three times).

Annex 19

COMPARATIVE ECONOMIC ANALYSIS OF SMALL HYDROPOWER AND DIESEL GENERATION, MADAGASCAR, 1984 (reference size of 100 kW power station)

	HYDRO	DIESEL			
Installed cost	4000.0	950.0	US$/kW		
Life of investment	35.0	10.0	years		
Capital recovery factor	0.104	0.163			
kWh/kW installed/y	4380.0	4380.0	load 50%		
Costs					
Depreciation	414.8	154.6	US$/y	Diesel	186.0 FMG/1
Staff	2.9	29.2	US$/y		
Operation and Maintenance	18.0	44.7	US$/7	Ex.Rate	625.0
Overhead	37.9	49.1	US$/y	kWh/1	2.5
Total fixed	473.6	277.6	US$/y		
Fixed/kWh	0.108	0.06	US$/kWh		
Variable/kWh	0.001	0.14	US$/kWh		
Total	10.91	20.62	US¢/kWh		

Basic cost data and parameters adapted from CI Power Ltd. report.

SOLAR ENERGY RESOURCE AND SAMPLE ECONOMIC ANALYSIS OF SOLAR WATER HEATING, MADAGASCAR, 1984

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
BESALAMPY TOTAL	5,70	5,80	5,80	5,80	5,20	4,80	5,00	5,70	6,60	7,10	7,10	5,50	2132,21
FRACTION -16,5	0,53	0,57	0,65	0,78	0,87	0,90	0,88	0,86	0,86	0,85	0,79	0,50	
TANA TOTAL	6,00	6,20	5,60	5,70	4,90	4,30	4,40	5,30	6,30	7,00	6,40	5,90	2068,33
FRACTION -19	0,51	0,58	0,54	0,68	0,68	0,64	0,63	0,66	0,71	0,72	0,59	0,49	
TOAMAS,TOTAL	5,90	5,90	5,20	4,80	4,20	3,50	3,60	4,30	5,40	6,10	6,20	5,90	1855,42
FRACTION -18	0,57	0,59	0,51	0,57	0,58	0,52	0,50	0,52	0,61	0,65	0,63	0,57	

TOTAL	G GLOBAL HORIZONTAL ACTUAL WEATHER	kWh/period	GJGM
FRACTION	INSOLATION FRACTION	(no units)	FSER
BEAM FRACTION		(no units)	FDIR
DIRECT CLEAR	G DIRECT HORIZONTAL CLEAR WEATHER	kWH/period	GJDO

GJGM = GJDO/FDIR*(.35+.65*FSER)

Mission estimates: Optimistic Case

Daily water consumption	60,00 m^3/d	Solar system eff'y	45,00%
Water temperature	60,00 C	Collector area	710,00 m^2
Final energy requirement	1016,86 MWh/y	Collector cost	210,00 US$/$m^2$
Discount rate	10,00%	Solar system cost	149,10 US$1,000'
Solar contribution	65,00%	Fuel saved	76,00 toe/y
Solar energy available	2060,00 kWh/m^2/y	Financial savings	20,00 US$/y 1,000'
		Annual am,solar	19,60 US$/y 1,000'

WIND ENERGY POTENTIAL AND ECONOMIC ANALYSIS, 1984

1. The potential has been assessed using meteorological data from the Service de la Meteorologie Nationale (10 years of records), which have been analyzed in computers locally.

2. A financial analysis has been performed using the basic cost data from "Reliability, energy and cost effects of wind-powered generation "Argonne National Laboratory, 1980" from which 1985 costs had been projected.

3. The raw data used, as well as the results of the analysis are given hereafter. The cost of generating one kWh of power with wind has been related to an "equivalent cost of diesel oil", which is the price threshold for diesel oil above which it becomes more profitable to generate power from wind than from diesel oil. As can be seen, the lowest cost corresponds to the largest wind generator (2,500 kWe), and this cost is 272 FMG/liter, actually close to the economic cost of diesel oil in remote areas. However, two cost factors have not been included in the analysis: the cost of batteries to ensure a regular supply if the wind generator is not connected to a grid, and the additional cost of building the wind generator in a remote place. These two factors combined would likely increase the "equivalent cost".

WIND RESOURCE AND ECONOMIC ANALYSIS, MADAGASCAR, 1984

Site & Height above Ground Level	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Ranohira													
10 m	64.2	57.3	52.2	43.5	45.8	40.6	36.8	38.2	64.5	115.5	85.5	73.3	717.4
50 m	215.1	193.3	175.8	157.9	173.9	157.1	137.3	139.5	351.7	214.1	272.8	241.0	2,429.5
Tolеary													
10 m	43.0	33.1	40.6	37.6	32.5	35.5	35.6	49.1	46.8	61.3	52.4	40.9	507.5
50 m	143.1	112.9	136.9	122.8	111.7	121.0	120.5	157.9	154.7	197.5	166.6	135.7	1,681.3
Faux-Cap													
10 m	192.3	281.4	318.6	280.7	241.0	174.6	184.1	136.5	145.8	178.7	348.8	184.6	2,667.1
50 m	460.7	655.3	709.3	653.0	583.2	435.3	443.9	346.9	370.4	435.7	808.6	448.8	6,351.1

Equipment Specification Rated Output	Capital $/kWh	Operating & Maintenance $/kWh	Output (MWh/year) 5m/s	6m/s	7m/s	Capital Cost Escalation for Local Conditions	
10 kWe	2,139.0	0.015	22.4	31.5	42.7	0.5	or 50%
200 kWe	1,764.0	0.015	300.8	476.8	636.2	0.5	or 50%
2.5 MWe	1,873.0	0.015	4,423.8	6,796.1	9,313.4	0.5	or 50%

Cost/kWh	10 kW		200 kW		2,5 MWe	
	FMG	US$	FMG	US$	FMG	US$
I. Analysis for Areas with Average Annual Wind Speed 5m/s						
Capital	117,7	0,188	144,6	0,231	130,5	0,209
Operating & Maintenance Cost	9,4	0,015	9,4	0,015	9,4	0,015
Total	127,1	0,203	154,0	0,246	139,8	0,224
Equivalent Cost/ltr of Diesel Delivered	254,1	0,407	307,9	0,493	279,7	0,447
II Analysis for Areas with Average Annual Wind Speed 6m/s						
Capital	83,7	0,134	91,2	0,146	84,92	0,136
Operating & Maintenance	9,4	0,015	9,4	0,015	9,4	0,015
Total	93,1	0,149	100,6	0,161	94,3	0,151
Equivalent Cost/ltr of Diesel Delivered	186,1	0,298	201,2	0,322	188,6	0,302
III Analysis for Areas with Average Annual Wind Speed 7m/s						
Capital	61,7	0,099	68,4	0,109	62,0	0,099
Operating & Maintenance	9,4	0,015	9,4	0,015	9,4	0,015
Total	71,1	0,114	77,7	0,124	71,3	0,114
Equivalent Cost/ltr of Diesel Delivered	142,2	0,228	155,5	0,249	142,7	0,228

Notes: a/ Unit of Measurement: $kWh/m^2/period$.
b/ Period of Observation: January 1972-December 1981 - includes Bet% limit.
c/ Interest rate assumed at 10% over 15 years.
d/ Thermal power generation costs of the oil plus 25% for other charges is assumed. Diesel produces 2,5 kWh/l thus, for each kWh saved, the financial savings are equivalent to 1,2 l oil.

Source: Mission estimates.

CURRENT AND PROJECTED DEMAND FOR WOODFUELS FOR HOUSEHOLDS MADAGASCAR

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Population ('000)																	
Total Population	8452,0	8174,0	8984,1	9262,1	9549,8	9734,9	10036,7	10347,8	10668,6	10999,3	11340,3	11691,8	12054,3	12425,0	12813,2	13210,4	13620,0
Highlands Urban																	
Antananarivo	452,0	471,8	498,5	523,2	549,4	577,7	606,6	636,9	668,8	702,2	737,3	774,7	812,9	853,6	896,2	941,1	988,1
Antsirabe	81,3	85,4	89,6	94,1	98,8	103,8	109,0	114,4	120,2	126,2	132,5	139,1	146,1	153,4	161,0	169,1	177,5
Fianarantsoa	70,6	74,5	78,1	82,0	86,1	90,4	95,0	99,7	104,7	109,9	115,4	121,2	127,2	133,6	140,3	147,3	154,7
Other	154,5	162,2	170,3	178,8	187,8	94,7	99,4	104,4	109,6	115,1	120,8	126,9	133,2	139,9	146,9	154,2	161,9
Total Highlands Urban	758,6	796,5	836,4	878,2	922,1	866,7	910,0	955,5	1003,2	1053,4	1106,1	1161,4	1219,4	1280,4	1344,4	14,116	1481,2
Lowlands Urban																	
Mahajanga	68,4	71,8	75,4	79,2	83,1	87,3	91,6	96,2	101,0	106,1	111,4	117,0	122,8	128,9	135,4	142,2	149,3
Toamasina	72,9	76,5	80,4	84,4	88,6	93,0	97,6	102,5	107,6	113,0	118,7	124,6	130,8	137,4	144,3	151,5	159,0
Toliary	62,4	65,5	68,8	72,2	75,8	79,7	83,7	87,9	92,3	96,9	101,8	106,9	112,2	117,8	123,7	129,8	136,4
Other	274,3	288,0	302,4	317,5	333,4	490,7	515,2	541,0	568,0	596,4	626,3	657,6	690,5	725,0	761,2	799,2	839,3
Total Lowlands Urban	478,0	501,9	527,0	553,3	581,0	750,7	788,2	827,6	869,0	912,5	958,1	1006,0	1056,3	1109,1	1164,5	1222,8	1284,0
Highlands Rural	3175,9	3619,0	3924,7	4033,0	4144,1	4180,5	4294,3	4410,8	4530,1	4652,7	4777,2	4905,1	5035,9	5169,8	5306,7	5445,8	5589,7
Lowlands Rural	3499,5	3596,4	3696,1	3798,1	3902,7	3937,0	4044,3	4155,9	4266,2	4381,3	4498,9	4619,4	4742,6	4868,6	4997,5	5135,3	5264,1
Urban Woodfuels Consumption																	
Bois de Feu (thousand tonnes)																	
Antananarivo	31,6	33,2	34,9	36,6	38,5	40,4	42,5	44,6	46,8	49,2	51,6	54,2	56,9	59,7	62,7	65,9	69,2
Antsirabe	5,7	6,0	6,3	6,6	6,9	7,3	7,6	8,0	8,4	8,8	9,3	9,7	10,2	10,7	11,3	11,8	12,4
Fianarantsoa	5,0	5,2	5,5	5,7	6,0	6,3	6,6	7,0	7,3	7,1	6,1	6,5	6,9	9,4	9,8	10,3	10,8
Other	10,8	11,4	11,9	12,5	13,1	6,6											
Total Highlands Urban	53,1	55,8	58,5	61,5	64,5	60,7	63,7	66,9	70,2	73,7	77,4	81,3	85,4	89,6	94,1	98,8	103,8
Mahajanga	6,8	7,2	7,5	7,9	8,3	8,7	9,2	9,6	10,1	10,6	11,1	11,7	12,3	12,9	13,5	14,2	14,9
Toamasina	7,3	7,7	8,0	8,4	8,9	9,3	9,8	10,3	10,8	11,3	11,9	12,5	13,1	13,7	14,4	15,1	15,9
Toliary	6,2	6,6	6,9	7,2	7,6	8,0	8,4	8,8	9,2	9,7	10,2	10,7	11,2	11,8	12,4	13,0	13,6
Other	27,4	28,8	30,2	31,8	33,3	49,1	51,5	54,1	56,8	59,6	62,6	65,8	69,0	72,5	76,1	79,9	83,9
Total Lowlands Urban	47,8	50,2	52,7	55,3	58,1	75,1	78,8	82,8	86,9	91,2	95,8	100,6	105,6	110,9	116,5	122,3	128,4
Charbon de Bois (thousand tonnes)																	
Antananarivo	63,3	66,4	69,8	73,3	76,9	80,9	84,9	89,2	93,6	98,3	103,2	108,4	113,8	119,5	125,5	131,[illegible]	13[illegible],3
Antsirabe	11,4	12,0	12,5	13,2	13,8	14,5	15,3	16,0	16,8	17,7	18,5	19,5	20,4	21,5	22,5	[illegible]	[illegible]
Fianarantsoa	9,9	10,4	10,9	11,5	12,0	12,7	13,3	14,0	14,7	15,4	16,2	17,0	17,8	18,7	19,6	20,6	[illegible]
Other	21,6	22,7	23,8	25,0	26,3	13,3	13,9	14,6	15,3	16,1	16,9	17,8	18,6	19,6	20,6	21,6	[illegible]
Total Highlands Urban	106,2	111,5	117,1	122,9	129,1	121,3	127,4	133,8	140,5	147,5	154,8	162,6	170,7	179,3	188,2	19[illegible]	[illegible]
Mahajanga	4,8	5,0	5,3	5,5	5,8	6,1	6,4	6,7	7,1	7,4	7,8	8,2	8,6	9,0	9,5	10,0	10,4
Toamasina	5,1	5,4	5,6	5,9	6,2	6,5	6,8	7,2	7,5	7,9	8,3	8,7	9,2	9,6	10,1	10,6	11,1
Toliary	4,4	4,6	4,8	5,1	5,3	5,6	5,9	6,2	6,5	6,8	7,1	7,5	7,9	8,2	8,7	9,1	9,5
Other	19,2	20,2	21,2	22,2	23,3	34,3	36,1	37,9	39,8	41,8	43,8	46,0	48,3	50,7	53,3	56,0	58,7
Total Lowlands Urban	33,5	35,1	36,9	38,7	40,7	52,5	55,2	57,9	60,8	63,9	67,1	70,4	73,9	77,6	81,5	85,6	89,9
Rural Woodfuels Consumption																	
Bois de Feu																	
Highlands Rural	2043,8	2100,5	2158,6	2218,2	2279,2	2299,5	2361,9	2425,9	2491,6	2558,7	2627,5	2697,8	2769,8	2843,4	2918,7	2995,6	3074,3
Lowlands Rural	1277,3	1312,7	1349,1	1386,5	1424,5	1437,0	1476,1	1516,2	1557,2	1599,2	1642,1	1686,1	1731,0	1777,0	1824,1	1872,2	1921,4
Total	3321,1	3413,2	3507,7	3604,5	3703,7	3736,5	3838,0	3942,1	4048,8	4155,9	4269,6	4383,9	4500,8	4620,4	4742,8	4867,8	4995,7
Overall Totals																	
Charbon de Bois (Kt)	139,7	146,6	154,0	161,7	169,8	173,9	182,6	191,7	201,3	211,3	221,9						
Bois de Feu (Kt)	3422,0	3519,2	3618,9	3721,3	3826,3	3872,0	3980,5	4091,8	4205,9	4322,8	4442,8	4565,8	491,8	4821,0	4955,5	5089,0	5227,9
Charbon de Bois (ktwe)	1241,6	1303,7	1368,9	1437,8	1509,7	1545,8	1621,1	1704,2	1789,4	1878,9	1972,8	2071,5	2175,1	2283,8	2398,0	2517,9	2647,8
Bois de Feu (ktwe)	3422,0	3519,2	3618,9	3721,3	3826,3	3872,0	3980,5	4091,8	4205,9	4322,8	4442,8	4565,6	4691,8	4821,0	4955,3	5089,0	5227,9
Total	4663,6	4822,8	4987,8	5158,6	5335,5	5417,8	5603,6	5796,0	5995,3	6201,7	6415,6	6637,2	6866,9	7104,6	7351,3	7606,8	7611,7
Charbon de Bois (ktoe) a/	99,8	104,7	110,0	115,5	121,3	124,2	130,4	136,9	143,8	150,9	158,5	166,4	174,8	183,5	192,6	202,3	212,4
Charbon de Bois (Ktoe) b/	390,0	409,5	429,9	451,4	474,0	485,5	509,8	535,3	562,0	590,1	619,6	650,6	683,1	717,3	753,2	790,8	830,4
Bois de Feu (Ktoe)	1074,8	1105,3	1136,8	1168,8	1201,8	1216,1	1243,9	1285,1	1321,0	1357,7	1395,4	1434,0	1473,6	1514,2	1555,9	1598,5	1642,0

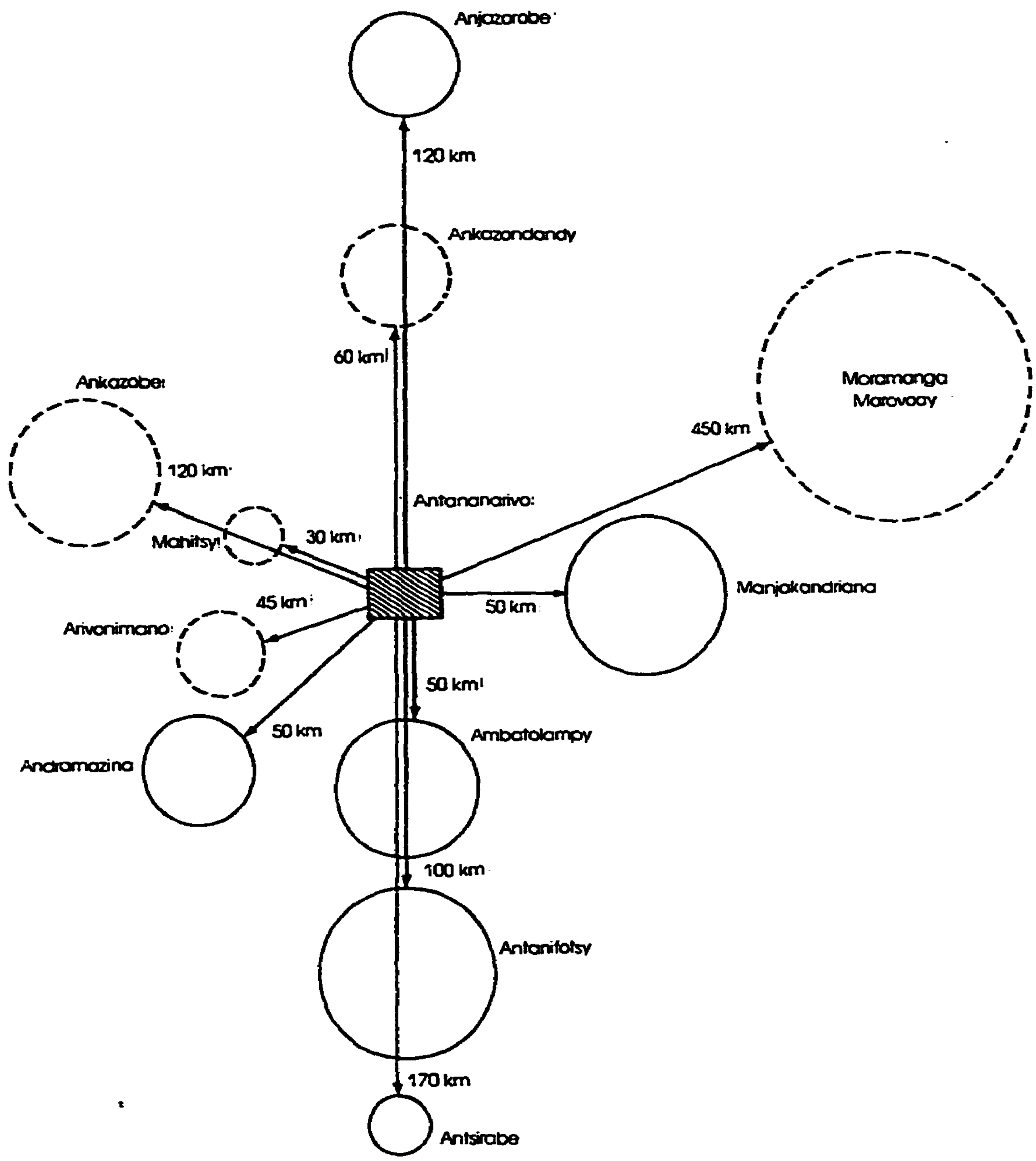
Assumptions

Starting Population	9134,9
Overall Growth	1,031
Starting Tana Population	577,7
Urban Population Growth	1,1
Propn, Highland Rural	0,5
Per Cap BF Highlands Urba	70,0
Per Cap BF Lowlands Urba	100,0
Per Cap CB Highlands Urba	140,0
Per Cap CB Lowlands Urba	70,0
Per Cap BF Highlands Rurl	550,0
Per Cap BF Lowlands Rurl	365,0
Tonnes wood (25mc)/Tonne Charcoal	8,9
Tonnes CB per toe	1,4
Tonnes BF per toe	3,2

a/ Secondary energy.

b/ Primary energy.

Location of the Main Accessible Woodfuels Resources (1984)



Source: Mrs Ranarijaona's thesis E.E.S.S. Antanaw·ɔrivo

World Bank—26939

MAIN COAL-BEARING AREAS

Overview

1. Seven areas including five principal coalfields, have been identified as coal exploration targets where coal is known or its presence is inferred. These are, scanning from SW to NE along the Morondava basin fringe:

Sakamena coalfield	]	
Sakoa coalfield	]	South of
Vohibory coalfield	]	Onilahy River
Ianapera coalfield	]	
Imaloto coalfield	]	North of
Ranohira-Beroroha area	]	Onilahy River
Malaimbandy-Ranotsara area	]	

All of these areas have been mapped and coal outcrops have been further exposed in trenches and adits. There has also been core drilling in the Sakamena, Sakoa and Vohibory coalfields which, along with the coal analyses, show that the Sakoa coalfield contains the most important known resource in Madagascar of moderate ash, medium volatile, steam coal. No systematic evaluation of the coal resources has been made but estimates for the total Sakoa basin are as high as 1,000 million tonnes. This figure is acceptable but may be slightly higher than justified by the available data. It is concluded that the in situ geological resource is very large.

2. The mineable reserves (>1.4 m thick, less than 300 m of cover) have been estimated at 173 million tonnes in the Sakoa coalfield, which is one of five fields identified in the basin. Of these reserves Saarberg Interplan, a reputable and competent consulting group, estimate 81.79 million tonnes of coal recoverable by underground methods and 2.4 million tonnes recoverable by open-pit methods in a limited area of the field. BP Coal in their recent (1984) review of the total coal-bearing area of southwestern Madagascar have estimated 22.9 million tonnes of coal recoverable by open-pit methods to a maximum 10:1 volume to volume ratio between Mahasora and the Savazy River. To a maximum 5:1 v/v ratio, they estimate 250,000 tonnes recoverable in the proposed "mini-pit" area near the former Sakoa mine. It is important to note that these recoverable reserves are all contained in the Sakoa coalfield and exclude any for the Imaloto field, which has been recognized by BP (and also by Utah and Amax) as the priority prospect for coal reserves mineable by open-pit methods. The prospects for the discovery of additional open-pit reserves in other fields are discussed below.

The Main Coalfields

3. The Sakamena coalfield is the most southerly and westerly of the coalfields and is nearest to the sea, which lies some 100 km due west. It has been extensively explored with the drilling of 19 boreholes, digging of some 35 trenches and the driving of 6 adits into the coal measures. The coalfield strikes NE-SW with a dip between 25° and 30° to the NW. It forms a straight outcrop 19 km long which is subdivided into a northern segment from the basement high at Tamotamo to the Sakamasay River and a southern, inferior strip from Bealitsy to beyond Analahiva where the seams are described as thin, anastomosing and high in ash. The coal measures vary from 40 m to over 100 m thickness but the coal occurs in five zones of variable bands within the basal 40 m interval. Seam No. 5, at the top, varies from less than 1 m to 2.4 m with a raw ash of 31% air dried basis (adb) and volatile matter of 25% adb. Seam No. 4 is slightly better, ranging up to 4.7 m in thickness and having a raw ash of 26% and a volatile matter content of 24% adb. Data held on the other seams are incomplete but they are of limited economic interest.

4. A 3 km wide horst of basement schists and gneiss separates the Sakamena coalfield from the sediments which include Sakoa coalfield to the east. The Sakoa coalfield, like the Sakamena, has been explored by mapping, trenching, drilling and exploratory mining. Some 42 trenches and pits were opened, 13 boreholes were drilled and adits were driven into the coal of the main seams at 7 sites; one of these, at Andranomanintsy, was developed into the "Sakoa mine". The strike of the coal measures (NW-SW) is parallel to those in the neighbouring Sakamena coalfield and they dip NW between 20° and 30°. The outcrop is divided into four continuous strips by faults. The coal measures are normally about 100 m thick and outcrop for 30 km in a 1 km wide strip. The five coal seams which are found in the basal 40 m have been correlated in the southern 10 km of the Sakoa coalfield and are numbered one to five from the base upward. The only seams of economic importance are the Nos. 4 and 5 seams at the top of the sequence. They are usually thicker than 2 m and seam No. 4 has an average raw ash value of 20% adb. The Mavono-Andranomanintsy-Mamboreko-Mahosaio part of the Sakoa coalfield is the most prospective part where the full five seam sequence has been drilled and where coal zones of up to 9 m with a raw ash of 28% including direct bands have been found. The seams dip at about 25°. In seam No. 4 there is a 3 to 4 m section which has a raw ash as low as 16%. This southern part of the coalfield is 10 km long and has been the subject of at least three mine feasibility studies in 1953 (BUMIFOM), 1978 (KOPEX), and 1979 (Saarburg-Interplan). The mine at Andranomanintsy was developed into the No. 4 seam and the No. 5 seam and a total production of 53,000 tonnes was extracted between 1941 and 1972. At Andranomanintsy the coal was mined mainly from the 4-5 m thick seam No. 4. The coal had the following quality on an air-dried run-of-mine basis: ash 16.4%, volatile matter content 25.4%, and sulphur 0.8%.

5. The Vohibory coalfield lies north-east of and strikes parallel to the Sakoa coalfield. The northern limit is a fault system 2 km south of the Onilahy River. Coal seams up to 3 m thick have been recorded but the Vohibory coalfield is notable for its variable seam thicknesses which are greatest in the south, nearest the Sakoa coalfield. The dip also varies from 6° to 45° and faulting appears common. The strike varies from N-S to E-W giving the coalfield a sinuous outcrop over 14 km still following the NE-SW general trend of the basin. Exploration work has been concentrated in the southern 4 km where 2 boreholes and 4 trenches show two coal zones, the upper between 0.9 and 1.8 m thick with an ash of 49% in borehole AS1 and up to 5 coal bands in a 12-15 m thick lower coal zone. The best quality band is the basal 1.75 m with 10% ash (basis unknown).

6. The Ianapera coalfield lies in an isolated fault trough in the basement 9 km SE of Vohibory and 20 km due east of Andranomanintsy (the Sakoa mine). The trough measures 7 km by 11 km and coal measures outcrop in several separate short (apprxomately 1 km) strips limited by faults. The fault direction is mainly N-S with a secondary NNE-SSW set. Dips vary enormously (10° to 40°) in amount and direction and are clearly affected by the faulting. There has been no drilling but 4 sites have been trenched. There is a conflict in the two sources of data as to the number of seams and there are no logs of the trenches. A 1928 report describes five seams totalling 8.5 m of which one seam is 3 m thick. This is contradicted by a later report (1956) which describes only one very banded seam with only 0.10 to 0.60 m of coal containing 29% ash.

7. In the Imaloto coalfield, the coal measures outcrop over an area some 12 km by 4 km where the Imaloto river joins the Onilahy some 150 km from the sea. Structurally, the coal measures form a gently dipping syncline in the southern half of the coalfield which changes to a fault bounded monocline in the north. Dips range from 0° to 15° but low dips of about 5° predominate. The four coal seams were described in 1954 as mainly carbonaceous mudstone but a later report (1957) describes one seam with an average thickness 1 m as having 15% raw ash. As the only coalfield with coal measures dipping at less than 10°, the Imaloto area could have the greatest potential for open-cast mining if a thick seam(s) of clean coal could be found. An optimistic interpretation of the data available assumes that only weathered coal remnants have been found at surface and that it is possible that thick coal seams have yet to be discovered. If thick, good quality coals could be found near the surface at Imaloto, it could prove to be a significant open-cast coal resource. BP are presently proposing the evaluation of this field as their primary objective.

Other Areas

8. The central area from Beroroha to Ranshira some 170 km long between the Imaloto coalfield and the outcrop of Sakoa Group Red Series SE of Malaimbandy has been mapped as having no Sakoa Group sediments at outcrop. The younger Sakamena Group sediments overstep the Sakoa Group

and are locally faulted against basement. It is speculated that Sakoa Group sediments may not be deeply buried and careful mapping and stratigraphic drilling could detect them. Evidence against there being any Sakoa Group sediments within 500 m of surface is strong, however. Four oil exploration boreholes at Beroroha, Ranohira and near the Imaloto coalfield showed Sakamena Group resting on basement at 720 m. Seismic sections by Geosource for Occidental Petroleum confirm the graben structure of the Karoo trough and hint at Sakoa Group sediments at depths (about 6000 m). This picture reportedly agrees with the results of a gravity survey carried out in 1954 in the early search for oil. A faulted contact between lower Sakamena sediments and basement is reported to have been observed by BP Coal and OMNIS geologists some 10 km north of the N7 road near Ranohira. The area is not believed to be prospective for mineable coal.

9. In the Malaimbandy-Ranotsara area, Upper Sakoa Group sediments (Red Series) are known in a series of fault blocks on both sides of the line of the NW-SE trending Ranotsra fault. This fault is a major basement fracture with a history of movement before, during and after the deposition of the Sakoa Group. No coal measures have been found in this area but it is speculated that there may be a coalfield concealed under the 100 km long outcrop. It is a very low priority prospect.

STRATIGRAPHY OF MAIN COALFIELDS

Period	Epoch	Group	Sub-Group/ Formation	Thickness m	Facies
	Pliocene-Recent				Continental/Lacustrine
Tertiary	Eocene-Miocene				Marine
Cretaceous					Marine/Continental
					Lignite
Jurassic		Sakahara			Mixed facies
Jurassic	Lower)	Isalo	(II (Makay)	1000 to ± 200	Sandstone, claystone
	)		(		local BROWN COALS
Triassic	Middle to Upper)		(I	3000 to ± 200	Piedmont deposits and
					salt
Triassic	Lower)	Sakamena	(Upper	500 to 600	Continental
Permian	Upper)		(Middle	200-	Marine mudstone and
			(		limestone
			(Lower	2000 to 2600	Transitional marine
Permian	Middle)	Sakoa	(Vohitolia Lst	10 to 20	Marine Limestone
	Lower)		(Red Series	1000 to 1200	Continental
			(Coal Measures	10 to 200	Continental with COAL
			(Glacial Series	1 to 275	Fluvioglacial

LIGNITE RESOURCES

1. The principal lignite resources of Madagascar occur in the Antsirabe region of the central highlands of Madagascar. There are minor lignite occurrences in the western area of the country. Several exploration programs have been undertaken in the Antsirabe/Antanifotsy area since the deposit was first reported in 1912. The more significant investigations were undertaken by a private French company (1920-1927), the Service des Mines (1936), the U.S. Bureau of Mines (1961), and by the UNDP (1970). Limited exploitation of the resource took place in the period 1947-1949 when approximately 570 tonnes of lignite were mined by underground methods for use by the railway. The lignite deposit was reportedly reviewed as a potential raw material source for the Antsirabe cement plant presently under construction, but no data for this evaluation, if indeed it ever took place, could be located.

Antsirabe Area

2. The lignites are found in small depositinal basins in Pliocene sediments which were formed in intermontane lakes of limited extent resulting from the damming of valleys by extensive volcanic flows. The principal deposit is that at Antanifotsy. This deposit contains several seams of lignite associated with thin low grade oil shales but the seams are generally thin and often lenticular. The exploration has indicated that only one seam has sufficient reserves of a quality that would warrant consideration in any economic assessment of the mining potential. This seam, referred to as Seam 3, varies in thickness from 1.5 m to 2.0 m. Analysis of the lignite shows an ash content of 15-20% and a calorific value of between 1900 kcal/kg and 3000 kcal/kg. It is not totally clear on what basis these heat values were determined but the wide range probably reflects variations in both ash and moisture content of the samples. The lignite produced by the mine reportedly had a heat value of 4000 kcal/kg after drying to less than 20% moisture content. The run-of-mine lignite reportedly contained in excess of 45% moisture with consequent reduction in heat value. The sulphur content was relatively high at 2.5%.

3. Several reserve calculations have been made. The U.S. Bureau of Mines (1961) estimated the reserves for Seam 3 as:

Measured	18.3	million tonnes
Indicated	3.7	" "
Inferred	10.4	" "
Total	32.4	" "

A more recent estimate by the UNDP (1971) determined the reserves to be:

Proved	11.0	million tonnes
Probable	10.6	" "
Possible	32.0	" "
Total	53.6	" "

This more recent determination reflects data from the more extensive exploration work carried out by the UNDP. While the reserves and analytical information does not indicate a prime quality lignite, nevertheless if it were easily mineable the deposit would clearly have some economic potential. However, there are no reserves that could be recovered by open-pit methods. Furthermore, reports on both the small mine that operated and on the exploratory adits describe the seam as "faulted, lenticular and undulating". Additionally, there are references to "much water". It is concluded that there is no economic potential for the development of the lignites of the Antsirabe area in the foreseeable future.

Other Areas

4. Several occurrences of lignite have been reported in western Madagascar in the Isalo formation of Permian age. These occurrences have been investigated and the maximum thickness located is a 0.40 m seam in the Antsohihy area. A 0.12 m seam was reportedly worked in the Ambilobe area. In all cases, the seams are reported as lenticular. There is not believed to be any economic potential for the development of these resources.

Annex 27

CEMENT PRODUCTION AND COAL CONSUMPTION
(Tonnes)
Cimenterie de Amboanio (CIMA)

Year	Clinker Production	Cement Production	Coal Consumption
1968	61,024	67,743	19,840
1969	61,926	75,445	19,824
1970	62,787	75,216	20,032
1971	65,325	76,930	20,775
1972	48,597	64,177	16,479
1973	56,655	69,863	18,128
1974	54,095	61,447	16,180
1975	61,253	58,021	20,261
1976	54,200	69,904	17,761
1977	41,892	52,229	14,216
1978	53,652	66,000	20,589
1979	51,917	61,535	19,394
1980	52,266	60,014	20,723
1981	n.a.	36,357	11,932*
1982	n.a.	36,060	11,980*
1983	n.a.	36,235	12,078*
1984 (to end Sep.)	n.a.	28,597	n.a.

*Estimated from cement production.

Source: CIMA.

Annex 28

CEMENT CONSUMPTION
(Tonnes)

Year	Total	Local Production	Cement Imported	kg/capita
1968	128,000	67,743	60,678	
1969	141,000	75,445	53,445	
1970	148,000	75,216	72,680	
1971	170,000	76,930	93,206	
1972	126,000	64,177	61,632	
1973	113,000	69,863	43,496	
1974	88,000	61,447	26,891	11.3
1975	109,000	58,021	50,985	
1976	92,000	69,904	23,892	11.1
1977	95,000	52,227	38,473	
1978	144,000	66,000	48,706	17.0
1979	108,000	61,535	46,565	
1980	126,560	60,014	66,548	14.3
1981	n.a.	36,357	n.a.	
1982	n.a.	36,060	n.a.	
1983	n.a.	36,235	n.a.	

Note: Some minor inconsistencies which reflect different data sources exist in the above table.

Source: Feasibility Study for Amboanio Cement Plant, Keramoprojekt Trencin (Polytechna, Prague), December 1983.

CEMENT - PROJECTED PRODUCTION AND DEMAND
('000 tonnes)

	1984	1985	1986	1987	1988	1990	1991	1992	1993	1994	1995	2000
1. Mahajanga	35 (12)b/	35 (12)	10 (4)	30 (8)	60 (16)	60 (16)	75 (20)	75 (20)	75 (20)	75 (20)	75 (20)	75 (20)
2. Ibitsy	--	30 (5)b/	60 (10)	90 (15)	100(16.5)	100 (16.5)	110 (18)	110 (18)	120 (20)	130 (22)	140 (24)	180 (30)
3. Total Production	35	65	70	120	160	160	185	185	195	205	215	255
4. Demand	120	153	166	183	196	226	228	239	242	255	264	280
5. Surplus (Deficit)	(85)	(88)	(96)	(63)	(36)	(66)	(43)	(54)	(47)	(50)	(49)	(25)
6. Total Coal Requirements	12	17	14	23	32.5	32.5	38	38	40	42	44	50

Note: (a) Demand projection is based on (i) population rise from 10.0 million (1984) to 14.0 million (2000);
(ii) per capita annual cement consumption rising from 15 kg (1984) to 25kg (2000).
(b) Coal requirements by plant are shown in parentheses.
(c) Mahajanga assumed to be rehabilitated in 1986-87.
(d) Additional kiln installed at Ibitsy in 1993. (Alternative is expansion at Mahajanga).

COAL DEMAND ('000 TONNES)
(by type)

	1984	1985	1986	1987	1988	1990	1991	1992	1993	1994	1995	2000
1) Cement Industry												
a) Low Volatile a/	--	5	10	15	16.5	16.5	18	18	18	20	20	20
b) Medium Volatile	12	12	4	8	16	16	20	20	20	22	24	30
Total Cement Industry	12	17	14	23	32.5	32.5	38	38	40	42	44	50
2) Potential Other Uses	1	3	5	10	10	10	10	10	10	10	10	10
3) Total Demand	13	20	19	28	32.5	42.5	48	48	50	52	54	60
4) Potential Demand for Indigenous Coal 1(a)+2	13	15	9	13	26	26	30	30	30	32	34	40

a/ Under construction kilns at Ibitsy (Antsirabe) will accept only low volatile coal, which must be imported.

Source: Mission estimates.

IMPORTED COAL COSTS, 1977-1983

		1977		1978		1979		1980		1981		1983	
1.	Year	1977		1978		1979		1980		1981		1983	
2.	Tonnes	2,665		20,815		18,354		22,126		4,789		4,459	
		FMG	US$	FMG	US$	FMG	US$	FMG	US$	FMG	US$	FMG	US$
3.	F.O.B. Maputo	22,621,926	92,071.33	67,859,325	744,057.29	144,680,069	680,254.20	181,008,359	856,641.55	no information		94,258,096	225,180
3a.	F.O.B. Maputo/tonne		34.55		35.75		37.06		38.71				50.50
4.	Sea Freight	14,382,103	58,555.22	103,841,104	460,288.16	104,890,911	493,140.16	127,748,355	604,582.84			48,256,598	115,283.69
4a.	Freight/tonne	5,397	21.96	4,989	22.11	5,715	26.87	5,773	27.32			10,822	25.85
5.	Bank Charges	596,248		7,126,810		4,155,550		3,878,148				1,322,473	
6.	Custom Charges	290,646		1,547,154		87,065		142,748				789,713	
7.	Total Cost	37,891,103		280,374,303		255,823,895		312,777,610				144,626,880	
8.	Cost per tonne (CIF Manajanga)	14,218	57.86	13,470	59.71	13,829	63.01	14,136	66.90	16,900	62.42	32,434	77.49
9.	Unloading	n.a		n.a.		n.a.		n.a.		n.a.		10,748,611	
10.	Labor	n.a.		n.a.		n.a.		n.a.		n.a.		2,035,284	
11.	Total Cost Unloaded	n.a.		n.a.		n.a.		n.a.		n.a.		157,410,775	376,050.01
12.	Loss (tonnes)	n.a.		n.a.		n.a.		n.a.		n.a.		555	
13.	Cost/tonne CIF Landed Manajanga	n.a.		n.a.		n.a.		n.a.		n.a.		40,330	96.34
14.	Exchange Rate (FMG per (US$)	245.70		225.60		212.70		211.30		270.21		418.59	

n.a. -- not available.

Source: CIMA

Power Generation and Consumption (JIRAMA), 1973-1983

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
1. Installed Capacity (MW)	(1)	92,0	100,2	100,2	104	103	114	120	133	204	204
Thermal	(1)	52,5	60,7	60,7	62	61	72	73	86	99	99
Hydro	(1)	39,5	39,5	39,5	42	42	42	47	47	105	105
2. Generation											
Gross	228,605	244,559	245,845	254,552	271,264	282,309	312,164	335,683	337,683	342,680	360,328
Thermal	64,908	87,454	172,082	82,700	90,114	166,667	194,577	188,113	183,129	114,360	112,292
Hydro	163,697	157,105	173,763	171,852	181,150	115,642	117,587	147,570	154,254	228,320	247,946
Station Supply	(1)	(1)	(1)	(1)	(1)	7,434	8,560	9,753	9,689	8,866	14,669
Net	(1)	(1)	(1)	(1)	(1)	274,875	303,604	325,930	327,694	333,814	345,569
Losses a/	(1)	(1)	(1)	(1)	(1)	29,832	24,646	30,372	24,917	33,840	32,657
3. Sales (MWh)	203,280	217,970	219,609	228,954	235,783	245,043	278,958	295,558	302,777	299,970	312,912
HV and MV	131,400	147,756	149,126	154,779	157,627	161,477	187,890	196,662	197,878	195,813	206,014
Direct Customers	(103,788)	(122,900)	(123,300)	(126,776)	126,621	128,568	150,436	159,552	158,320	157,944	164,366
Administration	(14,554)	(12,206)	(12,660)	(13,818)	14,621	15,751	16,690	16,546	18,569	16,703	18,890
Others b/	13,058	(12,650)	(13,166)	(14,185)	16,385	17,158	20,494	20,564	20,989	21,166	22,758
LV	71,880	70,214	70,483	74,175	78,156	83,566	91,068	98,896	104,899	104,157	106,898
Residential	53,382	51,795	51,525	54,834	57,994	62,064	68,027	74,277	80,610	83,822	86,716
Public Lighting	8,709	8,780	9,153	9,011	9,239	9,685	10,097	9,828	9,016	6,196	5,431
Motor Drive	9,789	9,639	9,805	10,330	10,923	11,817	12,944	14,791	15,272	14,139	14,751
4. Fuel Consumption											
Combustible											
Fuel Oil	(1)	(1)	(1)	(1)	8,071,488	15,345,378	21,669,900	23,299,161	25,626,864	12,572,126	13,502,727
Gas Oil	(1)	(1)	(1)	(1)	(1)	25,924,824	32,525,671	28,868,196	25,013,687	20,312,130	18,169,236

a/ Technical losses and unbilled consumption.
b/ Water pumping (JIRAMA).
( ) Estimated

HV - high voltage
MV - medium voltage
LV - low voltage

POWER GENERATION AND CONSUMPTION, INTERCONNECTED SYSTEM, 1973-1983

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
1. Installed Capacity (MW)	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4	61.4	126.9	126.9
Thermal	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	27.0	34.5	34.5
Hydro	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	92.4	92.4
2. Generation (MWh)											
Gross	153,157	155,147	155,383	161,571	173,755	176,859	189,778	200,342	201,842	207,525	221,448
Thermal	4,752	17,946	875	10,615	12,306	80,765	91,526	83,123	76,579	9,009	6,093
Hydro	148,405	137,201	154,508	150,956	161,449	96,094	98,252	117,219	125,263	198,516	215,355
Station Supply	(1)	(1)	(1)	(1)	(1)	1,561	1,665	1,685	1,741	1,740	4,574
Net	(1)	(1)	(1)	(1)	(1)	175,298	188,113	198,657	200,101	205,785	216,874
Losses a/.	(1)	(1)	(1)	(1)	(1)	17,104	15,541	18,669	18,085	25,601	24,582
3. Sales (MWh)	138,151	140,229	139,566	146,559	154,062	158,194	172,572	179,988	182,016	180,184	192,292
HV and MV	92,639	95,642	95,248	99,127	104,389	106,190	110,335	119,603	117,255	115,702	125,707
Direct Customers	71,531	(77,029)	(75,845)	(77,972)	81,844	83,691	90,794	93,928	88,881	88,627	95,368
Administration	(10,722)	(8,779)	(9,083)	(9,829)	10,142	10,109	10,637	11,210	13,078	11,556	13,622
Others b/	(10,386)	(9,834)	(10,320)	(11,326)	10,402	12,390	14,904	14,465	15,296	15,519	16,717
LV	45,512	44,587	44,318	47,432	49,673	52,004	56,237	60,385	64,761	64,482	66,585
Residential	33,596	32,758	32,319	35,143	37,419	39,287	42,631	46,302	50,684	52,788	54,782
Public Lighting	5,133	5,122	5,288	5,214	5,115	5,235	5,528	5,175	4,921	3,349	3,074
Motor Drive	6,792	6,707	6,711	7,075	7,139	7,482	8,078	8,908	9,156	8,345	8,729
4. Fuel Consumption Combustible											
Fuel Oil	(1)	(1)	5,046	1,455,857	1,534,288	9,347,378	9,854,000	10,693,161	13,764,164	2,170,326	1,272,727
Gas Oil	(1)	(1)	253,022	1,464,233	1,915,830	12,834,124	15,225,704	11,882,459	6,499,351	711,138	292,369
5. Peakload (kW)	30,200	31,430	29,720	32,460	33,420	34,400	37,990	39,980	41,460	44,600	45,300

a/ Technical losses and unbilled consumption.
b/ Water pumping (JIRAMA).
() Estimated

HV - high voltage
MV - medium voltage
LV - low voltage

INTERCONNECTED ZONE (ZI)
POWER CONSUMPTION FORECAST (GWh)

YEAR	ANTANANARIVO			ANTISIRABE							OTHER R.I.						TOTAL R.I.		
	BT	MT	S/T	BT	MT.T	COTONA + EXT.	STAR	KOB-AMA	MAM-ISOA	S/T	BT	MT.T	PAP-MAD	RDN	SOMA-COU	S/T	BT	MT.T	S/T
1983	57.1	51.5	108.6	4.3	2.9	37.0	2.0	1.6	0.2	48.9	5.1	3.7	17.4	6.6	2.0	34.8	66.6	125.7	192.3
1984	60.6	54.1	114.7	4.5	3.0	39.1	2.9	1.6	0.3	51.4	5.9	4.3	18.0	6.9	2.7	37.8	71.0	132.9	203.9
1985	64.3	56.8	121.1	4.7	3.2	50.4	3.8	3.0	2.5	67.6	6.9	4.9	18.0	6.9	2.7	39.4	75.9	152.2	228.1
1986	68.1	59.6	127.7	4.9	3.3	50.4	5.2	3.0	2.5	69.3	8.1	5.6	18.0	6.9	2.9	41.5	81.1	157.4	238.5
1987	72.2	62.6	134.8	5.1	3.5	54.3	6.8	3.0	2.5	75.2	9.4	6.4	18.0	6.9	3.3	44.0	86.7	167.3	254.0
1988	76.5	65.7	142.2	5.3	3.7	54.3	8.2	3.0	2.5	77.0	11.0	7.4	18.0	6.9	3.3	47.6	92.8	174.0	266.8
1989	81.1	69.0	150.1	5.5	3.8	54.3	8.6	3.0	2.5	77.7	11.6	7.9	20.0	6.9	3.3	49.7	98.2	179.3	277.5
1990	86.0	72.5	158.5	5.8	4.0	54.3	8.6	3.0	2.5	78.2	12.3	8.3	20.0	6.9	3.3	50.8	104.1	183.4	287.5
1991	91.2	76.1	167.3	6.0	4.2	54.3	8.6	3.0	2.5	78.6	13.0	8.9	20.0	6.9	3.3	52.1	110.2	187.8	298.0
1992	96.6	79.9	176.5	6.3	4.4	54.3	8.6	3.0	2.5	79.1	13.7	9.4	20.0	6.9	3.3	53.3	116.6	192.3	308.9
1993	102.4	83.9	186.5	6.6	4.6	54.3	8.6	3.0	2.5	79.6	14.5	10.0	20.0	6.9	3.3	54.7	123.5	200.1	325.6
1994	108.6	88.1	196.7	6.8	4.9	54.3	8.6	3.0	2.5	80.1	15.3	10.6	20.0	6.9	3.3	56.1	130.7	202.1	332.9
1995	115.1	92.5	207.6	7.1	5.1	54.3	8.6	3.0	2.5	80.6	16.2	11.3	20.0	6.9	3.3	57.7	138.4	207.5	345.9
1996	122.0	97.1	219.1	7.4	5.3	54.3	8.6	3.0	2.5	81.1	17.1	12.0	20.0	6.9	3.3	59.3	146.5	213.0	259.5
1997	129.3	102.0	231.3	7.7	5.6	54.3	8.6	3.0	2.5	81.7	18.1	12.7	20.0	6.9	3.3	61.0	155.1	218.9	374.0
1998	137.1	107.1	244.2	8.1	5.9	54.3	8.6	3.0	2.5	82.4	19.1	13.5	20.0	6.9	3.3	62.0	164.3	225.1	389.4
1999	145.3	112.4	257.7	8.4	6.2	54.3	8.6	3.0	2.5	83.0	20.2	14.4	20.0	6.9	3.3	64.8	173.9	231.6	405.5
2000	154.0	118.1	272.1	8.8	6.4	54.3	8.6	3.0	2.5	83.6	21.4	15.3	20.0	6.9	3.3	66.9	184.2	238.4	422.6

BT - Low voltage
MT - Medium voltage
S/T - Subtotal

ISOLATED CENTRES (CI)
POWER CONSUMPTION FORECAST (GWh)

	Ambatondrakaka			Autres Centres Isoles (Basse-Tension)								Total C.I.		
Year	BT	MT	ST	Tsiroa-noman-didy	Miari-narivo	Anka-zobe	Nosi-be Anala	Mana-kamba-hiny	Tsiazo Paniry	Mian-drivazo	S/T	BT	MT	Total
1983	0,68	0,30	0,98	0,22	0,14	0,04	0,02	0,02	0,05	0,06	0,55	1,23	0,30	1,53
1984	0,72	0,32	1,04	0,26	0,17	0,05	0,02	0,02	0,05	0,07	0,64	1,36	0,32	1,68
1985	0,77	0,35	1,12	0,32	0,21	0,06	0,03	0,03	0,06	0,09	0,80	1,57	0,35	1,92
1986	0,82	0,38	1,20	0,37	0,23	0,07	0,03	0,03	0,08	0,10	0,91	1,73	0,38	2,11
1987	0,87	0,41	1,28	0,44	0,28	0,07	0,04	0,04	0,10	0,12	1,09	1,96	0,41	2,37
1988	0,93	0,44	1,37	0,53	0,34	0,10	0,05	0,05	0,12	0,14	1,33	2,26	0,44	2,70
1989	0,99	0,47	1,46	0,57	0,40	0,11	0,05	0,05	0,13	0,15	1,46	2,45	0,47	2,92
1990	1,06	0,51	1,57	0,61	0,48	0,11	0,06	0,06	0,14	0,16	1,62	2,68	0,51	3,19
1991	1,13	0,55	1,68	0,65	0,57	0,12	0,06	0,06	0,15	0,17	1,78	2,91	0,55	3,46
1992	1,20	0,59	1,79	0,70	0,68	0,13	0,07	0,07	0,16	0,19	2,00	3,20	0,59	3,79
1993	1,28	0,63	1,91	0,75	0,81	0,14	0,07	0,07	0,17	0,20	2,21	3,49	0,63	4,12
1994	1,37	0,68	2,05	0,80	0,97	0,15	0,08	0,08	0,18	0,21	2,47	3,84	0,68	4,52
1995	1,46	0,73	2,19	0,86	1,16	0,16	0,08	0,08	0,20	0,23	2,77	4,23	0,73	4,96
1996	1,56	0,79	2,35	0,92	1,38	0,17	0,09	0,09	0,21	0,26	3,10	4,66	0,79	5,45
1997	1,66	0,85	2,51	1,00	1,64	0,19	0,09	0,09	0,22	0,26	3,49	5,15	0,85	6,00
1998	1,77	0,92	2,69	1,06	1,95	0,20	0,10	0,10	0,24	0,28	3,93	5,70	0,92	6,62
1999	1,88	0,99	2,87	1,14	2,32	0,21	0,11	0,11	0,26	0,30	4,45	6,33	0,99	7,32
2000	2,01	1,06	3,07	1,22	2,77	0,23	0,12	0,11	0,28	0,32	5,05	7,06	1,06	8,12

External Zones (ZE)
Power Consumption Forecast (GWh)

Grandes	Zones	Resultats 1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Antsiranana	BT	4,7	5,0	5,3	5,7	6,0	6,4	6,8	7,3	7,7	8,2	8,7	9,3	9,9	10,5	11,2	11,9	12,7	13,5
	MT/HT	3,1	3,1	3,2	5,1	5,4	5,5	5,8	6,0	6,2	6,4	6,8	6,9	7,1	7,3	7,4	7,7	7,9	8,1
	S/T	7,8	8,1	8,5	10,8	11,4	11,9	12,6	13,3	13,9	14,6	15,5	16,2	17,0	17,8	18,5	19,6	20,6	21,6
Nosy-Be	BT	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,5	1,5	1,5	1,5	1,5
	MT/HT	3,2	3,5	3,6	3,8	3,9	4,1	4,2	4,4	4,6	4,8	5,0	5,2	5,5	5,8	6,2	6,5	7,0	7,4
	S/T	4,6	4,9	5,0	5,2	5,3	5,5	5,6	5,8	6,0	6,2	6,4	6,6	6,5	7,3	7,7	8,0	8,5	8,9
Mahajanga	BT	7,4	7,8	8,3	8,8	9,3	9,8	10,4	11,0	11,6	12,2	12,9	13,7	14,4	15,3	16,1	17,1	18,0	19,1
	MT/HT	45,5	46,6	48,6	51,9	57,7	58,6	59,5	60,5	61,6	62,7	63,9	65,2	66,6	68,1	69,8	71,5	73,4	75,3
	ST	53,3	54,4	56,9	60,7	67,0	68,4	69,9	71,5	73,2	74,9	76,8	78,9	81,0	83,4	85,9	88,6	91,4	94,4
Antalaha	BT	0,9	1,0	1,1	1,1	1,2	1,3	1,3	1,4	1,5	1,6	1,7	1,8	1,9	2,0	2,2	2,3	2,4	2,6
	MT/HT	0,4	0,4	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8
	ST	1,3	1,4	1,5	1,6	1,8	2,0	2,1	2,3	2,5	2,6	2,8	3,0	3,2	3,4	3,7	3,9	4,1	4,4
Toamasina	BT	8,6	8,9	9,1	9,4	9,6	9,9	10,2	10,4	10,7	11,0	11,3	11,7	12,0	12,3	12,7	13,0	13,4	13,8
	MT/HT	11,8	12,7	13,1	17,7	18,4	18,6	18,8	19,0	19,2	19,4	19,7	19,9	20,1	20,4	20,7	20,9	21,2	21,5
	S/T	20,4	21,6	22,2	27,1	28,0	28,5	29,0	29,4	29,9	30,4	31,0	31,6	32,1	32,7	33,4	33,9	34,6	35,3
Fianarantsoa	BT	3,2	3,3	3,4	3,5	3,7	3,8	3,9	4,1	4,2	4,4	4,5	4,7	4,9	5,1	5,3	5,5	5,7	5,9
	MT/HT	1,6	1,9	2,1	3,4	4,5	4,6	4,8	5,0	5,1	5,3	5,6	5,8	6,0	6,3	6,6	6,9	7,2	7,6
	S/T	4,8	5,2	5,5	6,9	8,2	8,4	8,7	9,1	9,3	9,7	10,1	10,5	10,9	11,4	11,9	12,4	12,9	13,5
Manakara	BT	0,7	0,7	0,7	0,8	0,8	0,8	0,9	0,9	0,9	1,0	1,0	1,0	1,1	1,1	1,1	1,2	1,2	1,3
	MT/HT	0,3	0,3	0,4	0,5	0,6	0,6	0,6	0,7	0,7	0,7	0,8	0,8	0,8	0,9	0,9	1,0	1,1	1,1
	S/T	1,0	1,0	1,1	1,3	1,4	1,4	1,5	1,6	1,6	1,7	1,8	1,8	1,9	2,0	2,0	2,2	2,3	2,4
Toliary	BT	3,5	3,7	3,9	4,1	4,3	4,6	4,8	5,1	5,4	5,7	5,8	6,3	6,7	7,0	7,4	7,8	8,3	8,7
	MT/HT	12,2	12,7	12,8	14,9	15,8	15,9	16,1	16,3	16,4	16,6	16,9	17,1	17,3	17,6	17,9	18,2	18,5	18,9
	S/T	15,7	16,4	16,7	19,0	20,1	20,5	20,9	21,[illegible]	21,8	22,3	22,7	23,4	24,0	24,6	25,3	26,0	26,8	27,6
Morondava	BT	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,9	2,0	2,2	2,4	2,5	2,7	3,0	3,2	3,4	3,7
	MT/HT	0,4	0,4	0,4	0,4	0,5	0,5	0,5	0,6	0,6	0,7	0,7	0,8	0,8	0,9	0,9	1,0	1,1	1,2
	ST	1,4	1,5	1,6	1,7	1,9	2,0	2,1	2,3	2,5	2,7	2,9	3,2	3,3	3,6	3,9	4,2	4,5	4,9
Taolanaro	BT	0,9	0,9	1,0	1,1	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	2,0	2,1	2,3	2,4	2,6	2,8
	MT/HT	0,8	0,9	0,9	0,9	0,9	1,0	1,0	1,0	1,1	1,1	1,1	1,2	1,2	1,2	1,3	1,3	1,4	1,5
	ST	1,7	1,8	1,9	2,0	2,0	2,2	2,3	2,4	2,6	2,7	2,8	3,0	3,2	3,3	3,6	3,7	4,0	4,3
Autres Z.E.	BT	6,7	6,7	7,7	8,8	10,0	11,4	13,1	14,1	15,1	16,2	17,4	18,6	20,0	21,5	23,0	24,7	26,5	28,4
	MT/HT	0,3	0,4	0,4	0,5	0,5	0,6	0,7	0,8	0,9	1,1	1,2	1,4	1,6	1,8	2,1	2,3	2,7	3,1
	ST	7,0	7,1	8,1	9,3	10,5	12,0	13,8	14,9	16,0	17,3	18,6	20,0	21,6	23,3	25,1	27,0	29,2	31,5
TOTAL	BT	39,0	40,5	43,1	46,0	48,8	52,1	55,7	58,8	61,9	65,3	68,6	72,7	76,6	81,1	85,8	90,6	95,7	101,3
	MT/HT	80,1	82,9	85,9	99,6	108,8	110,7	112,8	115,2	117,4	119,8	122,8	125,5	128,3	131,7	135,3	138,9	143,2	147,5
	Tot.	119,1	123,4	129,0	145,6	157,6	162,8	168,5	174,0	179,3	185,1	191,6	198,2	205,1	212,8	221,1	229,5	238,9	248,8

FORECAST BALANCES OF ELECTRIC ENERGY (GWh)
TOTAL SYSTEM

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Consumption												
Interconnected System	203.9	228.1	238.5	254.0	295.3	306.5	316.9	327.9	339.3	354.6	364.5	378.0
Isolated Centers	1.7	1.9	2.1	2.4	2.7	2.9	3.2	3.5	3.8	4.1	4.5	5.0
External Zones	123.4	129.0	145.6	157.6	134.3	139.5	144.6	149.4	154.7	160.6	166.6	173.0
Total	329.0	359.0	386.2	414.0	432.3	448.9	464.7	480.8	497.8	519.3	535.6	556.0
Losses	42.8	43.1	46.3	49.7	51.9	53.9	55.8	57.7	59.7	62.3	64.3	66.7
Required Generation												
Thermal	131.4	134.0	152.5	165.8	143.2	149.0	154.3	160.1	166.0	172.5	179.4	180.7
Hydro	240.4	268.1	280.0	297.9	341.0	353.8	366.2	378.4	391.5	409.1	420.5	436.0
Total	371.8	402.1	432.5	463.7	484.2	502.8	520.5	538.5	557.5	581.6	599.9	622.7
Fuel Consumption (million liters)												
Fuel Oil	13.5	12.8	14.4	15.7	13.5	14.1	14.5	15.2	15.7	16.4	17.0	17.7
Gas Oil	25.4	30.3	34.6	37.7	32.6	34.0	35.3	36.4	37.7	39.4	40.8	42.5

Annex 36

FORECAST BALANCE OF ELECTRIC ENERGY AND CAPACITIES
(INTERCONNECTED SYSTEM), 1984-1995

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
CONSUMPTION (GWh)												
Antananarivo												
Low voltage	60.6	64.3	68.1	72.2	76.5	81.1	86.0	91.2	96.6	102.4	108.6	115.1
Medium voltage	54.1	56.8	59.6	62.6	65.7	69.0	72.5	76.1	79.9	83.9	88.1	92.5
Subtotal	114.7	121.1	127.7	134.8	142.2	150.1	158.5	167.3	176.5	186.3	196.7	207.6
Antsirabe												
Low voltage	4.5	4.7	4.9	5.1	5.3	5.5	5.8	6.0	6.3	6.6	6.8	7.1
Medium voltage	3.0	3.2	3.3	3.5	3.7	3.8	4.0	4.2	4.4	4.6	4.9	5.1
Large customers	43.9	59.7	61.1	66.6	67.7	68.4	68.4	68.4	68.4	68.4	68.4	68.4
Subtotal	51.4	67.6	69.3	75.2	77.0	77.7	78.2	78.6	79.1	79.6	80.1	80.6
Other Areas												
Low voltage	5.9	6.9	8.1	9.4	11.0	11.6	12.3	13.0	13.7	14.5	15.3	16.2
Medium voltage	4.3	4.9	5.6	6.4	7.4	7.9	8.3	8.9	9.4	10.0	10.6	11.3
Large customers	27.6	27.6	27.8	28.2	29.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2
Subtotal	37.8	39.4	41.5	44.0	47.6	49.7	50.8	52.1	53.3	54.7	56.1	57.7
Toamasina a/												
Low voltage	(8.9)	(9.1)	(9.4)	(9.6)	9.9	10.2	10.4	10.7	11.0	11.3	11.7	12.0
Medium voltage	(12.7)	(13.1)	(17.7)	(18.4)	18.6	18.8	19.0	19.2	19.4	19.7	19.9	20.1
Subtotal	(21.6)	(22.2)	(27.1)	(28.0)	28.5	29.0	29.4	29.9	30.4	31.0	31.6	32.1
Total	203.9	228.1	238.5	254.0	295.3	306.5	316.9	327.9	339.3	354.6	364.5	378.0
LOSSES	30.6	34.1	35.6	38.0	44.2	45.8	47.8	49.0	50.7	53.0	54.5	56.5
REQUIRED GENERATION (GWh)												
Thermal	3.1b/	3.1	3.1	3.1	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Hydro	231.4	259.1	271.0	288.9	336.0	348.8	361.2	373.4	386.5	404.1	415.5	431.0
Total	234.5	262.2	274.1	292.0	339.5	352.3	364.7	376.9	390.0	407.6	419.0	434.5
FIRM GENERATION												
Generation margin c/	351.1	323.4	311.5	293.6	250.5	237.7	225.3	213.1	200.0	182.4	171.1	155.5
LOAD FACTOR (%)	57	57	57	57	56	56	56	57	57	58	58	58
MAXIMUM DEMAND (MW)	47.0	52.3	54.9	58.5	69.2	71.8	74.3	75.5	78.1	80.2	82.5	85.5
Available Capacity d/	118	118	118	118	123	123	123	123	123	123	123	123
CAPACITY MARGIN												
(MW)	71	65.7	63.1	59.5	53.8	51.2	48.7	47.5	44.9	42.8	40.5	37.5
%	151	126	115	102	78	71	66	63	57	53	49	44

a/ Toamasina is assumed to be connected to the interconnected system in 1988.
b/ Annual fuel consumption (liters) - fuel oil 688,140 + gas oil 107,760.
c/ Assumes firm generation on the basis of an average hydrological year.
d/ Small thermal plants older than 20 years retired.

INSTALLED GENERATION CAPACITY

Plant	Type	No. of Units	Unit Capacity	Commissioning Date	Installed Capacity kW	Firm Capacity kW	Average Generation GWh p.a.	Dry-year Generation GWh p.a.
I. Hydropower plants								
A. Interconnected System								
Antelomita	Francis	6	6x1,360	1930-58	8,160	8,160	50	28
		1	1x640		640	640		
Mandraka	Pelton	4	4x6,000	1 - 04/56 2 - 04/56 3 - 11/66 4 - 05/71	24,000	24,000	81	45
Manandona	Francis	2	2x480	1 - 1932 2 - 1932	960	960	12	9.5
		1	1x640	3 - 06/60	640	640		
Andekaleka	Francis	2	2x29,000	1 - 06/82 1 - 06/82	58,000	58,000	500	427
B. Isolated Centers								
Ankazobe	Francis	1	1x50	1959	50	-	0.05	-
Ambohimidana	Francis	1	56	-	56	-	0.07	-
C. External Zones								
Toamasina	Francis	4	3x1,520 1x2,200	1931 1971	6,760	4,560	24.0	40
Vatomandry	Francis	3	1x90 2x40	1953 1953	170	40	0.3	0.3
Namorona	Francis	2	2x2,800	1980	5,600	2,800	8.5	25
Fianarantsoa Manandray	Francis	3	2x140 1x170	1932 1963	450	170	1.5	1.5

INSTALLED GENERATION CAPACITY

Plant	Type	Fuel	No. of Units	Unit Capacity	Commissioning Date	Installed Capacity kW	Available Capacity kW	Specific Consumption g/kWh
II. Thermal Power Plants								
A. Interconnected System								
Ambohimanambola	Pielstick	GO+Fuel	3	3x6,000	1 - 10/72	18,000	18,000	245
					2 - 08/73			
					3 - 05/81			
Antsirabe	MGO	GO	2	1x500	1 - 11/58	500	500	
				1x500	2 - 11/60	500	500	
	MAN	GO	2	2x1100	3 - 03/64	2,200	2,200	
					4 - 07/67			
			1	1x1,800	5 - 11/68	1,800	1,800	
	Pielstick	GO+Fuel	1	1x7,500	6 - 05/82	7,500	7,500	
Mandroseza	Sulzer	GO	1	1x720	1 - 09/49	720	720	
	Worthington	GO	2	2x1,040	2 - 1951	2,080	2,080	260
				3x6,000	3 - 10/72			
	SGCM	GO	1	1x1,200	4 - 06/55	1,200	1,200	
B. Isolated Centers								
7 Plants	Diesel	GO	21	26-180	1967-79	1,835		
C. External Zones								
45 Plants	Diesel	GO	135	6-9000	1950-83	63,130		

AUTOGENERATION CAPACITY, 1980

Place	Source	Installed Capacity (kW)
Societe Siramany Malagasy	Steam	13,625
Etablissement d'Ambilobe	Diesel	2,070
Secren A'ntsiranana	Diesel	4,505
Sucreries de Nossi-be et de la Cote-Est	Steam	3,435
(Exploitation de Nossi-be)	Diesel	490
Sirama Etablissement de Namakia	Steam	3,675
	Diesel	1,483
Ste Kraoma		
Exploitation Andriamena	Diesel	3,075
Exploitation Befandriana	Diesel	160
Sucrecies de Nossi-be de la Cote-Est	Steam	1,450
	Diesel	1,845
Cie des Ciments Malgaches Amboanio	Diesel	2,850
SOLIMA Raffinerie de Toamasinie	Diesel	2,610
Ste d'exploitation du Complex Industriel et Agricole de Moron-dava	Diesel	2,462.5
Societe H. et A. de Heaulme Fort Dauphin	Diesel	1,965
Societe Agricole du domain de Pechpeyron Amboasary Sud	Diesel	1,624
Ets. Gallois Fort Dauphin	Diesel	1,354
Ste Agricole Miniere et Industrielle Exploitation graphic Ambatomitamba	Diesel	1,040
Ste Malgache d'Industrie et d' Agriculture Agence d'Anomy	Diesel	975
Ste Rasolaarijao et Fils Ambatasoratra	Diesel	877
Cie Saliniere de Mas/car	Diesel	820
Ets. Gallois - Graphite Marovintsy	Diesel	121
- Graphite Antsira Kanso	Diesel	521
Samangoky (usines a Canaux)	Diesel	650

Place	Source	Installed Capacity (kW)
Societe du Sisal Malgache Amboasary-Sud	Diesel	560
Ste Murri Freres Sambara	Diesel	560
Ste Galland et Cie Andromosaba Alaotra	Diesel	548
SCIM Usine de Maikampango	Diesel	534.4
Fifabe Marovoay	Steam	270
	Diesel	255
Samangoky Morombe	Diesel	486
Papeteries de Madagascar Ambohimanambola	Steam	450
Ste Malgache Nippone de Viande Concetree Antonogombato	Diesel	435.5
C.F.D.T. Madagascar Usines d'Ambahikily et d'Ambilobe	Diesel	395
SORIFEMA - Vohidiala	Diesel	300
- Anjiro	Diesel	5
Ste des Mines d'Ampandrama Fort Dauphin	Diesel	260
Ste Union Des Micas Fort Dauphin	Diesel	250
Hopital Lutherian Manambaro	Diesel	217.5
Ests R. Izouard Graphine Perinet	Diesel	210
SEVMACAM Ambatofinandrahana	Diesel	210
Ste Rizerie d'Amparafaravola	Diesel	200
Ste Malgache de Conserverie Ambato-Boeri	Diesel	193.5
Ste Arsene Louis et Cie Andasifahatelo Parinet	Diesel	154
FIFATO Bezela	Diesel	153
Mahavelona Ets Ravanjiarivelo	Diesel	150
Etablissements L. Millot et Cie Andzavibe Sambara	Diesel	141
SOMALACA Rizerie Ambongalava Amparafaravola Aloatra	Diesel	137

Place	Source	Installed Capacity (kW)
Compagnie Nosy beenne d'Industrie Agricoles Ambohimena - Ambanja	Diesel	130
Ecole Normale Joffre Ville Antsiranana	Diesel	115
Ste Kadherbbay et Fils Maintirano	Diesel	108
Aladina Alibhay Isoanala Fort Dauphin	Diesel	105
Hopital d'Ambovombe Androy	Diesel	103
SINPA Sambava	Diesel	100
Tranombarotra Roso	Diesel	83
SINPA Miarinarivo	Diesel	75
Ets. Lachaize Ambohimahasoa	Diesel	75
Union des Cooperatives Agricoles du Sambirano et de Ifasy Ambanja	Diesel	75
Aladina Alibhay Isoanala	Diesel	60
Hopital Lutherien EJeda	Diesel	58
Ests. Rostaing Sahamany Bricke Ville	Diesel	55
Ets. Restaing, exploitation miniere Sahamanny Bricka Ville	Diesel	50
O.B.M. Mandritsara	Diesel	25
Folk Kam Ambanja	Diesel	25
C.E.G. Joffre-ville Antsiranana	Diesel	20
Societe d'Exportation de Produits Sambava	Diesel	17
Societe SHAM-CHUN WING et Cie Sambava	Diesel	16
Etablissement AH Seng Sambava	Diesel	16
SIAMA Maintirano	Diesel	10
SORIFEMA Vohidiala M.L.A.	Diesel	10
		62,088.4

ELECTRIC POWER INVESTMENT PROGRAM a/, 1985-1990
(in FMG million)

	1985	1986	1987	1988	1989	1990	Total
Hydropower Plants							
Ambodiroka - Preparatory	84	98	100	100	100	100	582
Ankorahotra - Studies					80	90	170
Microcentrales	380	240	990	1,200	1,400	1,700	5,910
Others	(580)	(360)	(400)	1000+(600)	2000+(670)	3000+(750)	9,360
	1,044	698	1,490	2,900	4,250	5,640	16,022
Thermal Power Plants (Isolated Centers)	356+(570)	840+(560)	940+(630)	1050+(710)	1180+(790)	1320+(890)	9,836
Transmission Network							
Ambodiroka-Mahajanga - prepartory			100	100	100	100	400
Antananarivo's-Antsirabe	100	112	1,490	1,180	100	100	3,082
Andekaleka-Tamatave	70	210	4,213	4,426			8,919
Others	467	216	315	395			1,393
	637	538	6,118	6,101	200	200	13,794
Distribution							
Existing Centers	1141+(430)	1540+(490)	1730+(550)	1930+(610)	2170+(690)	2430+(770)	14,481
New Centers	150	350	475	660	1,000	1,500	4,135
	1,721	2,380	2,755	3,200	3,860	4,700	18,616
Miscellaneous							
Materials & Tools	308	350	410	470	540	620	2,698
Others	274	420	470	530	600	660	2,954
	582	770	880	1,000	1,140	1,280	5,652
TOTAL	4,910	5,786	12,813	14,961	11,420	14,030	63,920

a/ Numbers in parentheses indicate rehabilitation of existing facilities.

Source: JIRAMA and mission estimates.

ELECTRIC POWER PLANNING

1. Electricité de France (EDF) carried out a study in late 1982 of the organization of planning within JIRAMA, the purpose of which was to identify weaknesses in the present arrangments and to recommend changes necessary to correct them. This note summarizes the main features of the EDF study. Like the study, it is divided into two parts: critical analysis of the present situation and proposed solutions.

Critical Analysis

Data Collection

2. A mass of data is collected by different departments within JIRAMA on all facets of its power operations, but the present arrangements suffer from the defects that:

   (a) the "Direction Zone Interconnectée" (DZI) and "Direction Zones Extérieures" (DZE), the two directorates which are the main sources of the data, use different methods of collection;

   (b) similarly, there is a lack of standardization in the presentation of statistical data, which detracts from their usefulness; and

   (c) there are sometimes great delays in circulating the production data collected by DZI and DZE.

Presentation of Statistics

3. The half yearly statistical bulletins prepared by the "Direction Clients" omits some important statistics, although they are available within JIRAMA. The missing items include certain production statistics for hydropower plants (hydrology and state of reservoirs) and thermal power plants (specific fuel consumption); details of plant availabilities and shutdowns for scheduled and unscheduled maintenance; energy delivered by substations at the MT level; frequency and duration of supply interruptions; statistics of energy invoiced (by value); data on population served; activity summaries for each power station; and summary reviews of the activities of the main JIRAMA departments.

4. No analysis of the available statistics is presented, in the form of an annual publication showing characteristic ratios or "performance indicators" for the latest and preceding years.

Demand Forecasting

5. Shortcomings noted in the present forecasting procedures are:
   (a) Not enough care is taken in medium-term demand forecasts to identify major new industrial loads, on occasion resulting in serious underestimates of demand. This partly reflects poor liaison between JIRAMA and Government, but partly also poor coordination by JIRAMA of its own direct relations with industry.

   (b) The multiplicity of different departments within JIRAMA which intervene in the same geographical zone or sector, often operate independently of each other.

Generation and Transmission

6. JIRAMA lacks a computer model for long-term system planning.

7. Planning and operational functions are confused. DZI, DZE, the "Direction Clients" and "Direction Grands Projets" are all involved independently in technical-economic studies of generation and transmission development, which shoud be the subject of a properly integrated planning approach.

8. Pre-feasibility studies of hydropower projects are carried out by either "Direction Grands Projets" or the "Departement Travaux", instead of being the responsibility of a single directorate or department.

9. Similarly, studies of diesel power projects are carried out by DZI, or by the "Departement Travaux" in the case of projects in the external zones under DZE, instead of being the responsibility of a single department, which would promote standardization and ease of maintenance.

10. There are also competing responsibilities for transmission studies, with the DZI, "Direction Projets" and "Direction Développement" all involved.

Distribution

11. Distribution works are programmed on an annual basis only, although programming beyond the budget year (e.g., for a three year period) is desirable, if only for indicative purposes.

12. It is not clear whether DZI and DZE, who establish their own individual distribution programs, use the same criteria in planning projects, or the same technical standards in their design and execution.

13. There is also a lack of defined criteria and methodology for determining priorities amongst the components of proposed distribution programs, taking account of financial constraints.

Rural Electrification

14. There is no defined rural electrification program, although the great majority of the population lives in rural areas, and nothing has been done to rank potential areas for electrification according to consistent economic criteria.

Conclusions

15. The summary conclusions drawn by EDF from its review of the present arrangements for system planning within JIRAMA are that:

(a) The planning function is dispersed amongst too many directorates, with the resulting risks of inconsistency, duplication of effort and increased costs.

(b) Some normal planning activities are not covered.

(c) There is some confusion of planning and project work (design, procurement of equipment and construction).

16. The coordination of planning is also hampered by the geographical split of operational responsibilities between DZI and DZE, with similar functions within their respective areas. This gives rise, in particular, to the following difficulties:

(a) Lack of standardization of equipment within JIRAMA, increasing both investment and operating costs. An example is the multiplicity of types of diesel generating plants.

(b) Absence of a global approach to generation and transmission problems, which is essential for proper evaluation of all options for system expansion.

(c) Problems in establishing uniform technical and economic criteria for generation and transmission on the one hand and distribution on the other (e.g., for the formulation of master plans).

Options for Improving Planning

Objectives

17. Reorganization of the present arrangements for power system planning in JIRAMA has two main objectives:

(a) Elimination of the present duplication of planning functions and responsibilities, which involve five directorates (DZI, DZE, "Direction Clients," "Direction Développement" and "Direction Grands Projets"). Three of these (DZI, DZE and "Direction Clients") are primarily concerned with operations, and two ("Direction Développement" and "Direction Grands Projets") with system development (generation and transmission).

(b) Separation of the system planning and equipment functions, and a regrouping of planning functions (for generation and transmission). The EDF study groups the planning functions into two categories, designated "Planning A", covering statistics, demand projections and tariff studies, at present under the "Direction Clients", and "Planning B", covering economic studies and investment planning (generation and transmission), in which "Direction Développement" and "Direction Grand Projets" are involved.

Eliminating Duplication

18. Achievement of the first of these objectives (ending the present duplication of planning activities) requires some reallocation of specific responsibilities, combined with clearer definition of the roles of individual directorates and departments in relation to planning. The specific EDF recommendations are as follows:

(a) Data collection: DZI and DZE should remain responsible for collection of data on production, transmission and distribution.

(b) Presentation of statistics: The synthesis and presentation of statistics collected elsewhere in JIRAMA should remain the responsibility of "Direction Clients", but the latter should maintain a close dialogue with the users of the statistics to ensure their needs are being served.

(c) Analysis of data: This should become the sole responsibility of the "Direction Clients", to which the "Service Statistique" of the "Direction Développement" should be transferred.

(d) Demand forecasts: DZI and DZE should have the main responsibility for forecasts at the local level within their areas, the other directorates at present involved (Clients, Développement and Grands Projets) providing assistance as necessary. Global forecasts for the whole JIRAMA system should be primarily the responsibility of "Direction Clients", with input from DZI (on the interconnected network) and "Direction Développement" and "Direction Grands Projets" (on new industrial demands). Liaison with government departments on national economic developments should also be the responsibility of "Direction Clients", which should take over the present functions of DZI, "Direction Développement" and "Direction Grands Projets" in this area.

(e) Investment planning (generation and transmission): At present three directorates (DZI, "Developpement" and "Grands Projets") are involved in both technical and economic aspects. However, DZI's essential concern is with the operation of the interconnected network, and its investment planning responsibilities should be transferred to "Direction Développement" or "Direction Grands Projets".

(f) Equipment and projects: At present there is duplication with regard to (i) thermal power projects, (DZI and "Direction Développement" and, within the latter, two departments with thermal station responsibilities); (ii) hydropower projects ("Direction Grands Projets" for those of 5 MW or more, and "Direction Développement" for those below 5 MW); (iii) transmission (DZI, "Direction Grands Projets" and "Direction Développement"). As with investment planning, DZI's functions should be transferred to the other two directorates.

(g) Civil works and erection (generation and transmission): Large hydropower schemes are executed by foreign contractors. JIRAMA constructs other generating stations (diesel and small hydro) and also transmission facilities. "Direction Développement" is already responsible for everything except work related to existing diesel stations, which it should also take over from DZI and DZE.

Options for Reorganization of Planning

19. The EDF study puts forward the following options for achieving the second objective above (Para. 17(b)):

Option 1

(i) Planning A functions remain with "Direction Clients", as at present.

(ii) Planning B functions become the exclusive responsibility of "Direction Développement", which remains responsible for "Travaux."

(iii) Responsibility for equipment centralized in "Directions Grands Projets".

Option 2

All planning functions (A and B) to "Direction Clients".

Option 3

All planning functions (A and B) to "Direction Développement".

Option 4

All planning functions (A and B) to a new directorate, "Direction Etudes et Planification".

NOTE: For each of options 2 - 4, which involve placing all planning functions in a single directorate, there are two variants, as follows:

(a) "Direction Grands Projets" retains responsibility for equipment.

(b) "Direction Grands Projets" is abolished following final completion of the Andekaleka hydropower project (for which it was originally set up). Its equipment and planning functions are transferred to "Direction Développement", and the separation of the planning and equipment functions is achieved by making them the responsibility of different departments within "Direction Développement".

20. Option 1 would leave the number of directorates unchanged and involve the least change in the present organization of planning, but it would risk blocking subsequent evolution towards Options 2 - 4. Options 2(b) and 3(b) would reduce the number of directorates by one; Option 4(a) would increase it by one.

21. The EDF study does not express a specific preference for any of the options, leaving the decision to JIRAMA, but it does express the view that:

(a) Options 2(b) or 3(b) are probably preferable if a relatively low level of investments in system expansion is anticipated, which seems likely in present circumstances;

(b) Option 4 is probably best if a large volume of investments is anticipated; and

(c) Option 4 would quickly require a general reorganization of JIRAMA's present structure, for which a separate study would be needed.

Annex 41

LOAD GROWTH FORECAST (GWh)
(3.5% per year)

1. Assuming the 3.5% annual growth, the load forecast is as follows:

Year	Interconnected System	Total Madagascar
1984	234.5	371.8
1985	242.7	384.8
1986	251.2	398.3
1987	260.0	412.2
1988	297.6	426.6
1989	308.0	441.6
1990	318.8	457.0
1991	329.9	473.0
1992	341.5	489.6
1993	353.4	506.7
1994	365.8	524.5
1995	378.6	542.8

2. Neither 5% nor 3.5% annual load growth would require additional power generation capacity in the Interconnected System nor have any impact on total investments in this system. However, if 3.5% p.a. load growth is assumed for the total JIRAMA system, it would result in about 26 GWh less required to meet power needs in the External Zones (30% of total) in 1995. This corresponds to the reduction of about 5.6 MW in the installed capacities of the External Zones. In money terms, if supplied by diesel generating sets ($900/kW), the savings would amount to about US$5 million in capital costs or 7% of the total JIRAMA investment program in 1985-1995.

DEMAND FOR PETROLEUM PRODUCTS, 1973-1985

	Unit	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
(a) In Original Units														
Butane	'000 tonne	3.7	4.0	4.0	4.7	5.3	4.8	4.6	4.7	3.8	2.6	2.4	2.4	2.8
Gasoline	'000 m^3	115.5	113.5	111.3	110.5	109.9	116.5	113.8	110.8	95.2	79.2	78.7	73.3	74.9
Aviation Gasoline	'000 m^3	-	-	-	-	-	3.4	1.9	1.8	1.5	1.3	1.4	1.4	1.0
Kerosene	'000 m^3	) 61.3	) 61.1	) 62.6	41.0	39.9	37.0	39.0	36.8	35.4	34.9	37.4	33.3	35.3
Jet Fuel	'000 m^3	)	)	)	20.6	23.7	24.6	29.0	28.4	25.1	20.8	22.8	21.7	24.0
Gas Oil	'000 m^3	177.1	175.5	169.7	147.2	146.6	163.3	182.0	183.1	169.9	149.1	147.4	146.7	150.6
Fuel Oil	'000 m^3	107.9	132.1	105.4	79.7	60.9	63.9	119.5	99.1	63.1	53.8	54.1	43.3	51.1
(b) In toe														
Butane	'000 toe	4.1	4.4	4.4	5.1	5.8	5.2	5.1	5.1	4.2	2.8	2.6	2.6	3.0
Gasoline	'000 toe	87.9	86.4	84.7	84.1	83.6	88.7	86.6	84.4	72.5	60.3	59.9	55.8	57.0
Aviation Gasoline	'000 toe	-	-	-	-	-	3.6	1.5	1.3	1.5	1.3	1.0	1.0	0.7
Kerosene	'000 toe	) 50.0	) 49.7	) 51.0	33.3	32.4	30.1	31.7	29.9	28.8	28.4	30.4	27.1	28.7
Jet Fuel	'000 toe	)	)	)	16.8	19.4	20.1	23.7	23.1	20.5	17.0	18.6	17.7	19.6
Gas Oil	'000 toe	152.6	151.3	146.3	126.8	126.3	140.7	156.8	157.8	146.4	128.5	127.0	126.4	129.8
Fuel Oil	'000 toe	99.4	121.8	97.1	73.4	56.1	58.9	110.1	91.3	58.1	49.6	49.9	39.9	47.1
Total		394.0	413.6	383.5	339.5	323.6	347.3	416.0	393.4	332.0	287.9	289.9	270.5	285.9

Source: SOLIMA.

PROJECTED DEMAND FOR PETROLEUM PRODUCTS, 1984/85-2000/01
HIGH SCENARIO FROM BEICIP'S FEASIBILITY STUDY OF OCTOBER 1985
('000 tonnes per fiscal year) a/

	84/85	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	1999/ 2000	2000/ 2001	Percentage growth rate per year since 93/94
Butane	2,3	2,6	3,1	3,6	4,1	4,7	5,3	5,9	6,5	7,0	7,6	8,2	8,8	9,5	10,3	11,1	8
Regular Gasoline	55,8	59,9	60,5	60,5	61,1	61,7	62,3	62,9	63,6	64,2	64,9	65,5	66,2	66,8	67,5	68,2	1
Super Gasoline	2,0	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,8	1,8	1,8	1,8	1
Naphta	-	24,0	24,0	24,0	24,0	24,0	24,0	24,0	24,0	24,0	24,0	24,0	24,0	24,0	24,0	24,0	0
Kerosene	28,3	34,7	33,0	31,7	32,6	33,8	35,1	36,5	38,0	39,9	41,9	44,0	46,2	48,5	50,9	53,5	5
Jet Fuel	16,5	16,6	16,8	16,8	17,0	17,2	17,6	17,9	18,2	18,6	18,9	19,3	19,7	20,1	20,5	20,9	2
Gas Oil	122,9	140,0	144,7	149,4	154,1	158,8	163,6	168,4	173,2	181,9	190,9	200,5	210,5	221,0	232,1	243,7	5
Zeren Fuel Oil c/	-	26,0	26,0	26,0	26,0	26,0	26,0	26,0	26,0	26,0	26,0	26,0	26,0	26,0	26,0	26,0	0
Fuel Oil 2	44,7	72,7	84,3	86,3	87,8	89,3	90,9	92,5	94,6	97,4	100,4	103,4	106,5	109,7	113,0	116,4	3
Bitumen	0,8	20,0	20,0	15,2	16,6	18,0	19,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	0
Total	273,3	398,2	414,1	415,2	425,0	435,2	445,5	455,8	465,8	480,7	496,3	512,6	529,7	547,4	566,1	585,6	

a/ Demand on domestic Malagasy market only.
b/ Actual figures from SOLIMA.
c/ Fuel oil for the Zeren fertilizer plant. It must contain less than 10 ppm of vanadium and less than 2% sulphur.
Source: BEICIP, Feasibility Study on the Rehabilitation of SOLIMA's Toamasina Refinery, October 1985.

PROJECTED DEMAND FOR PETROLEUM PRODUCTS, 1984/85-2000/01
LOW SCENARIO FROM BEICIP'S FEASIBILITY STUDY OF OCTOBER 1985
('000 tonnes per fiscal year) a/

	84/85	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	1999/ 2000	2000/ 2001	Percentage growth rate per year since 93/94
Butane	2.3	2.5	3.0	3.5	4.0	4.6	5.2	5.8	6.5	6.8	7.2	7.5	7.9	8.3	8.7	9.2	5
Regular Gasoline	55.8	54.0	54.3	54.9	54.9	55.5	55.5	56.1	56.1	56.7	57.2	57.8	58.4	59.0	59.6	60.2	1
Super Gasoline	2.0	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1
Kerosene	28.3	28.7	28.0	27.1	27.7	28.2	28.8	29.4	30.0	30.6	31.2	31.8	32.5	33.1	33.8	34.5	2
Jet Fuel	16.5	16.6	16.8	16.8	17.0	17.0	17.2	17.4	17.4	17.7	18.0	18.1	18.3	18.5	18.7	18.9	1
Gas Oil	122.9	138.1	139.8	140.6	143.4	146.3	150.7	155.1	159.8	164.6	169.5	174.6	179.9	185.2	190.8	196.5	3
Fuel Oil 2	44.7	46.8	47.7	48.7	49.6	50.6	51.7	52.7	53.8	54.9	56.0	57.1	58.2	59.4	60.6	61.8	2
Bitumen	0.8	20.0	20.0	15.2	16.6	18.0	19.0	19.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	0
Total	273.3	308.4	311.3	308.5	314.9	321.9	329.8	337.2	345.3	353.0	360.8	368.6	377.0	385.3	394.0	402.9	

a/ Demand on domestic Malagasy market only.
b/ Actual figures from SOLIMA.
Source: BEICIP, Feasibility Study on the Rehabilitation of SOLIMA's Toamasina Refinery, October 1985.

SOLIMA REFINERY MODERNIZATION

1. The facilities already available in the refinery's new visbreaking complex, built at a cost of about US$25.0 million in 1982, can be reorganized and remodelled to effect substantial secondary conversion of the residual fuel oil. This will significantly improve the refinery's operating flexibility and profitability. The additional investment required for such remodelling is roughly estimated to be US$8.0 million with a payout period of around 2.5 years.

2. The modifications involved are summarized as follows:

(i) The reduced crude from the distillation unit will be processed in a new vacuum flash unit to produce vacuum gas oil and vacuum residue. The cost of this unit (about US$5.0 million) is the major part of the additional investment cost.

(ii) The existing hydrotreater in the visbreaker complex will be converted into a mild hydro-cracking (MHC) unit by replacing the existing catalyst and incorporating minor changes in the facilities. The cost of this change is estimated to be around US$1.0 million.

(iii) Process the vacuum gas oil in the MHC unit to produce additional gasoline, diesel and low sulphur heavy gas oil.

(iv) Use 20,000 tonnes per year of the vacuum residue for bitumen manufacture.

(v) Process the remaining vacuum residue and the low sulphur heavy gas oil in the MHC of the existing visbreaker complex to produce gasoline and fuel oil.

3. The result of the above modifications in the processing of the atmospheric residue is a net increase in the production of gasoline and diesel oil at the expense of surplus residual fuel oil. A preliminary estimate of product pattern with and without the modifications using Arab light crude oil shows the following results:

	Refining without Modifications	Refinery after Modifications
	(all figures in tonnes per year)	
Feed stock processed (atmospheric residue from 500,000 tons/year of crude oil)	215,000	215,000
Products:		
Fuel gas	6,000	8,000
Gasoline	9,000	18,000
Diesel	-	37,000
Fuel Oil	180,000	132,000
Bitumen	20,000	20,000
Total	215,000	215,000

Note: The products from the primary distillation of crude oil will remain the same in both cases.

4. In summary, the costs of this modernization proposal are estimated as follows:

	US $ Million
Installation of new vacuum flash unit	5.0
Conversion of existing hydrotreater into a mild hydro-cracking unit	1.0
Other expenses (connections, contingencies, etc.)	2.0
Total	8.0

COMPOSITION OF PETROLEUM PRODUCT PRICES, 1977-84

Date of Effectiveness	1977 28 March	1979 12 July	--------1980-------- 4 April	 14 Nov.	1981 23 March	1982 17 May	1984 17 May
Regular Gasoline - FMG/L							
Price ex-depot	86,000	139,000	155,000	165,000	263,000	315,000	372,000
Distributors' margins	4,000	5,000	5,000	5,000	6,000	7,000	8,000
City transport	1,000	1,000	1,000	1,000	1,000	1,000	2,000
Retail price at the pump	91,000	145,000	161,000	171,000	270,000	323,000	382,000
Kerosene - FMG/L							
Price ex-depot	45,550	67,000	77,000	79,000	105,000	120,000	151,000
Distributors' margins	4,000	4,000	4,000	4,000	5,000	6,000	7,000
City transport	1,000	1,000	1,000	1,000	-	-	2,000
Retail price at the pump	50,550	72,000	82,000	84,000	110,000	126,000	160,000
Gas Oil - FMG/L							
Price ex-depot	48,650	71,000	83,000	85,000	122,000	142,000	178,000
Distributors' margin	2,750	4,000	4,000	4,000	4,000	5,000	6,000
City transport	1,000	1,000	1,000	1,000	1,000	1,000	2,000
Retail price at the pump	52,400	76,000	88,000	90,000	127,000	148,000	186,000
LPG (Butane) - FMG/Bottle 12.5 kg							
Price ex-depot	1,370	2,350	2,650	3,250	4,700	5,300	6,250
Distributors' margins	150	150	150	150	150	200	250
Retail price	1,520	2,500	2,800	3,400	4,850	5,500	6,500
Fuel Oil - FMG/L a/							
Price ex-depot	29,317	30,680	44,680	60,000	70,500	94,087	121,450

a/ These prices were in effect on 1 April 1977, 1 December 1979, 4 August 1980, 23 March 1981, 1 May 1982, 6 July 1983 and 17 May 1984.

Source: SOLIMA.

Annex 46

SELECTED POWER TARIFF LEVELS
(June, 1984)

Unit: FMG/kWh

	ANTANANARIVO	INTERCONNECTED SYSTEM	NEW SECTORS	OTHERS
	Residential	Antsirabe Residential	Residential	Maevatanana
Highest Tariffs	T1 (10 kWh): 55.61	T1 (10 kWh): 51.25	Flat Rate: 91.91	Flat Rate: 114.59
	T2 (>10 kWh): 108.88	T2 (>10 kWh): 93.03		
	FMMT Administrations Contractual	Grand Tana FMMT Administrations	FMBT Administrations	Toamasina FMMT Administrations Facultative >5 kVA
Lowest Tariffs	PF/month/kW: 297.55	PF/yr/kW: 12,870.35	Flat Rate: 63.02	PF/mo/kVA: 799.90
	T1 (1500 h): 26.17	T1 (600 h): 51.48		
	T2 (1000 h): 23.55	T2 (1000 h): 38.61		T1 (1200 h): 20.54
	T3 (>2500 h): 19.63	T3 (>1600 h): 17.90		T2 (1200 h): 16.07
				T3 (1200 h): 13.34
				T4 (>3600 h): 12.01

Notes: T = Tranche.
PF = Demand charge.
FMMT = Motive power, medium voltage.
FMBT = Motive power, low voltage.
Administrations = Consumers other than private individuals ("particuliers").

Source: JIRAMA.

Annex 47

RETAIL WOODFUELS PRICES IN ANTANANARIVO, 1973-84

Year	Current Prices FMG) Firewood	Charcoal	Consumer Price Index a/	Constant Prices (1978 FMG) Firewood	Charcoal
1973	3.0	8.6	69.5	4.3	12.4
1974	3.7	9.0	76.9	4.8	11.7
1975	4.7	10.0	84.2	5.6	11.9
1976	4.7	11.0	89.8	5.2	12.3
1977	4.9	13.8	93.6	5.2	14.8
1978	5.4	14.0	100.0	5.4	14.0
1979	6.9	14.0	111.2	6.2	12.6
1980	8.7	21.0	128.0	6.8	16.4
1981	13.9	25.4	162.2	8.6	15.7
1982	17.7	39.4	225.8	7.8	18.0
1983	19.0	45.0	291.1	6.5	15.5
1984	22.1 b/	55.1 b/	337.7 c/	6.5 c/	16.3 c/
Ratio 1984/1973	7.4	6.3	4.9	1.51	1.31

a/ INSRE (Composite General Cost of Living Index).

b/ Mission measurements - average of several.

c/ Assuming a 1984 inflation rate of 16%.

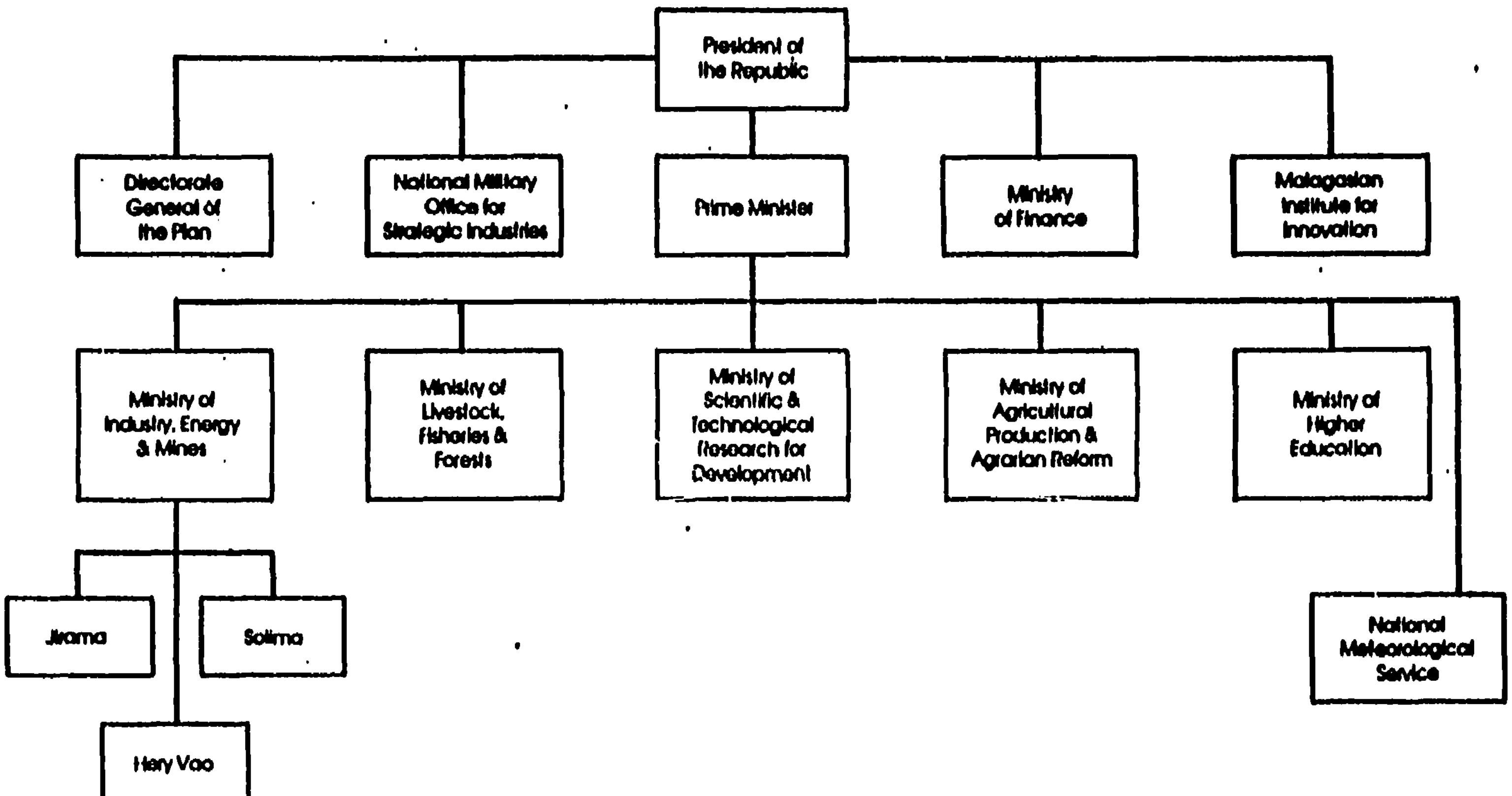
Annex 48

SAMPLE SURVEY OF WOODFUELS PRICES AND MARKETING
Madagascar, Late October, 1984

Location	Product	Unit Size	Retail Price per kg (FMG)	Quantity Sold per Week
Andriatany - near canal in Antananarivo	Charcoal Retail	Scoop approx. 1/3rd kg	54-60	35-55 bags of 25-30 kg
Anduatabenaky - near dyke in Antananarivo	Firewood Retail	in kgs as desired	15	5-7 tonnes
Imerinafanoany - on Antananarivo side (suburb)	Charcoal Retail	Scoop 0.32 kg	57	0.3 tonnes
Ambohdratino - suburb of Antananarivo (opposite "Magasin M"	Firewood Retail	Small Bundles 0.35 kg	17	0.17 tonnes
Near Angavokely (35 km from Antananarivo on road to Moramango)	Charcoal Wholesale	25 Kg bags	50	
Moramango (120 km from Antananarivo)	Charcoal Wholesale & Retail	25 kg bags & by kg	34 & 53	150 bags
Mahajina - 35 km from Moramango towards Antananarivo	Charcoal Wholesale	31-32 kg bags	27	150 bags
Ambohitavy - 64 km North of Moromango	Charcoal Wholesale	26 kg bags	24	variable

Source: Interviews of merchants and weighed and moisture assayed samples by team of DEF and mission members.

MADAGASCAR
Energy Sector Assessment
Organization of Energy Sector



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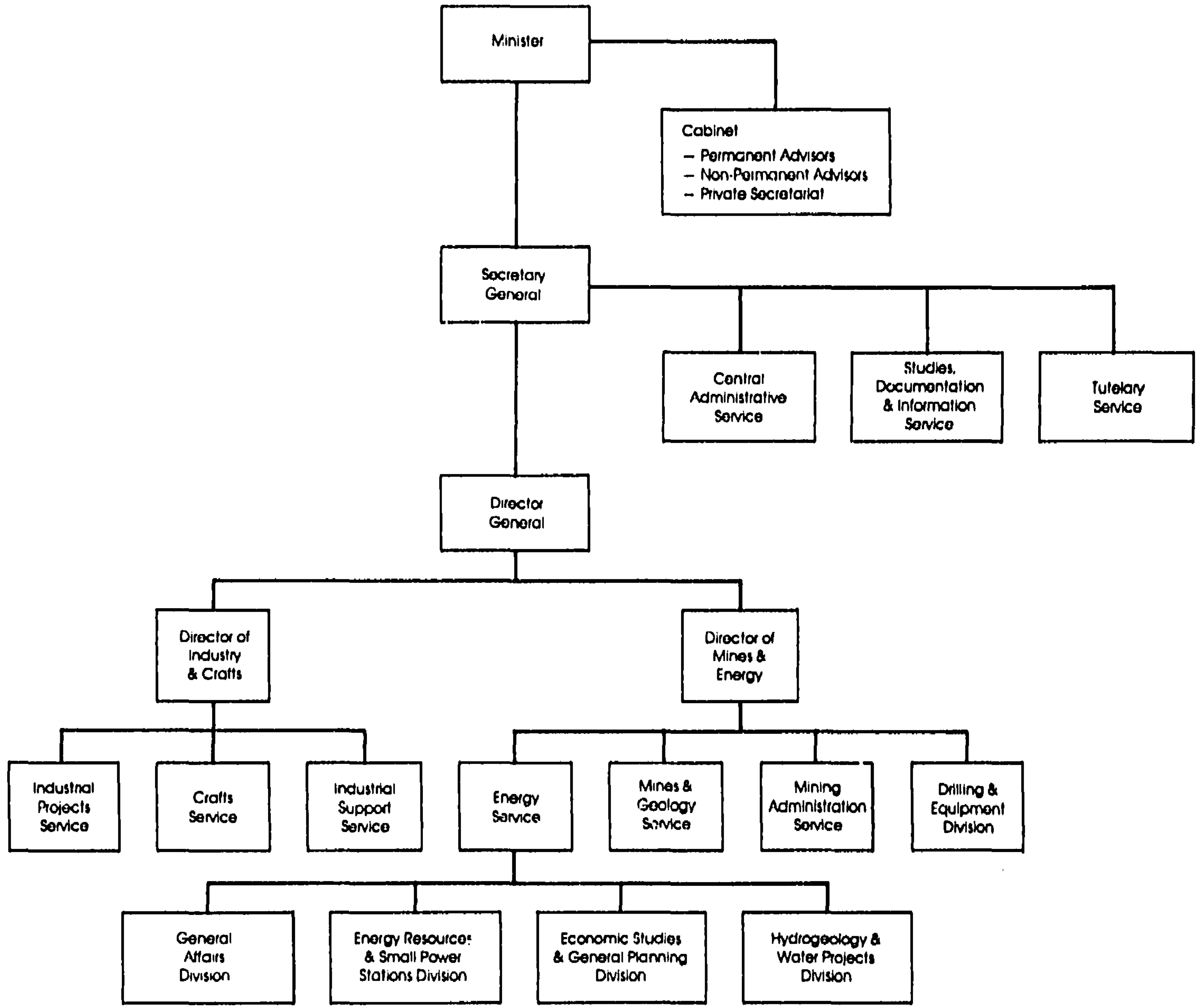
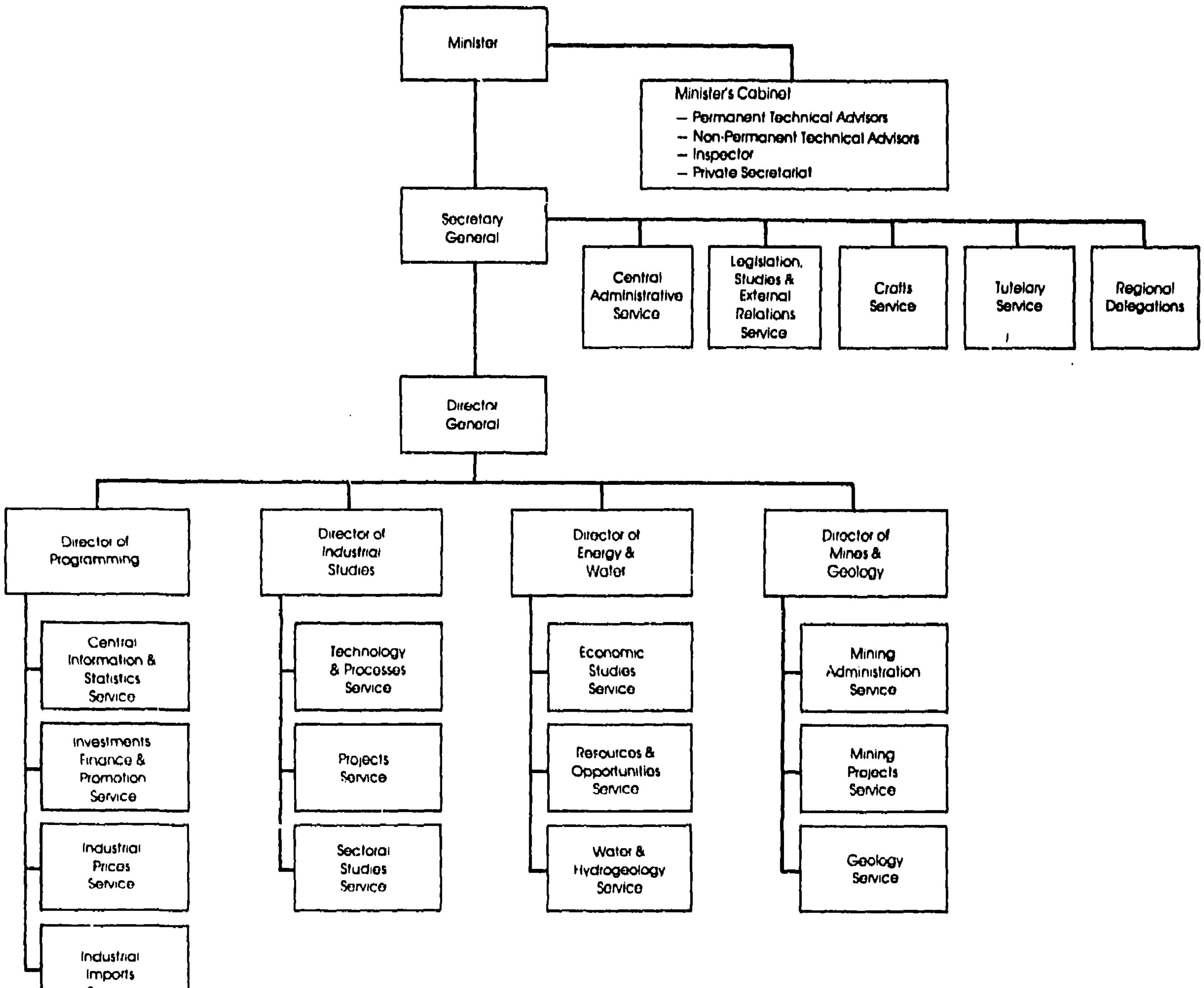
MADAGASCAR
Energy Sector Assessment
Existing Organization of Ministry of Industry, Energy and Mines



World Bank—26892

Energy Sector Assessment
New Organization of Ministry of Industry, Energy and Mines



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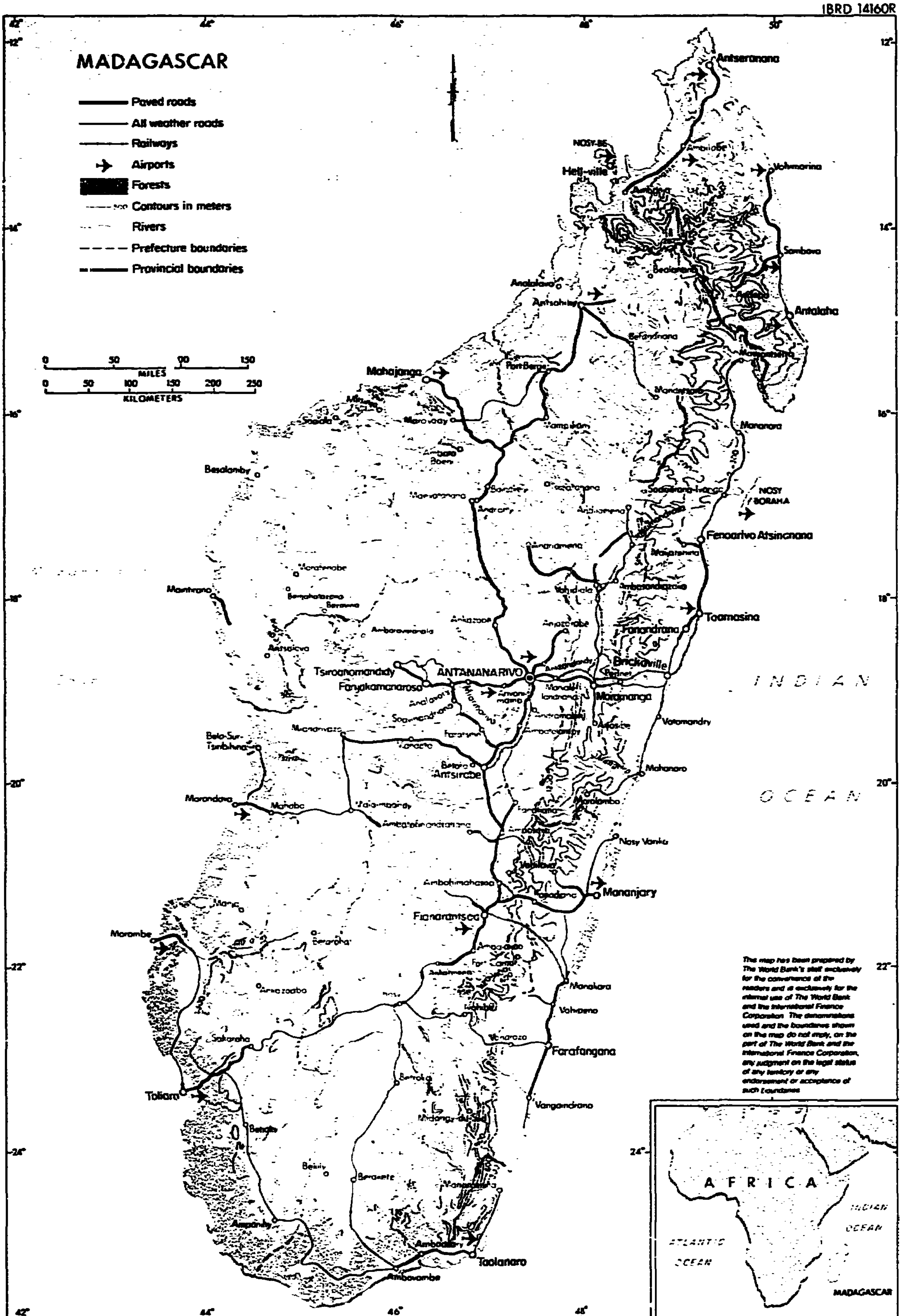
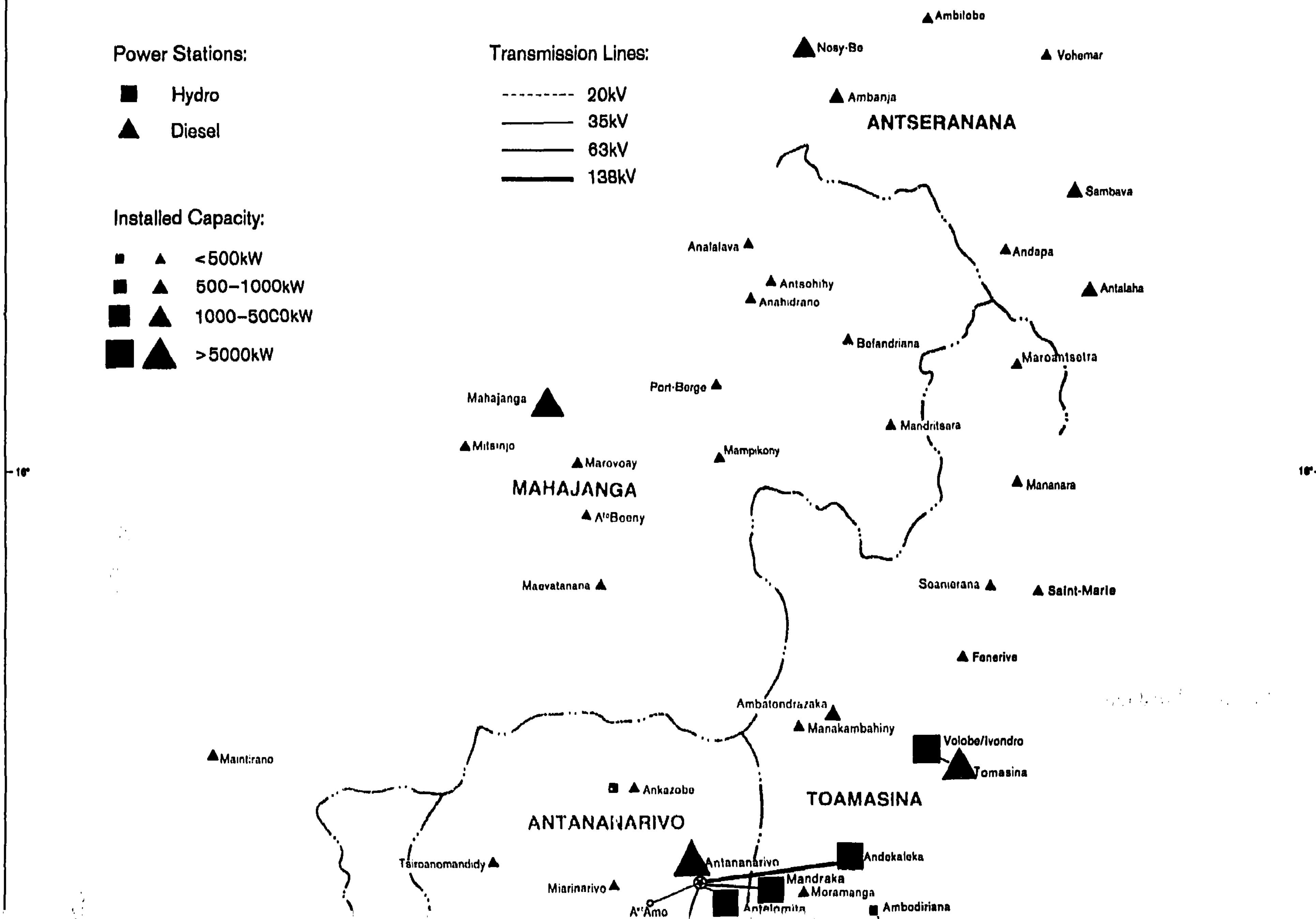
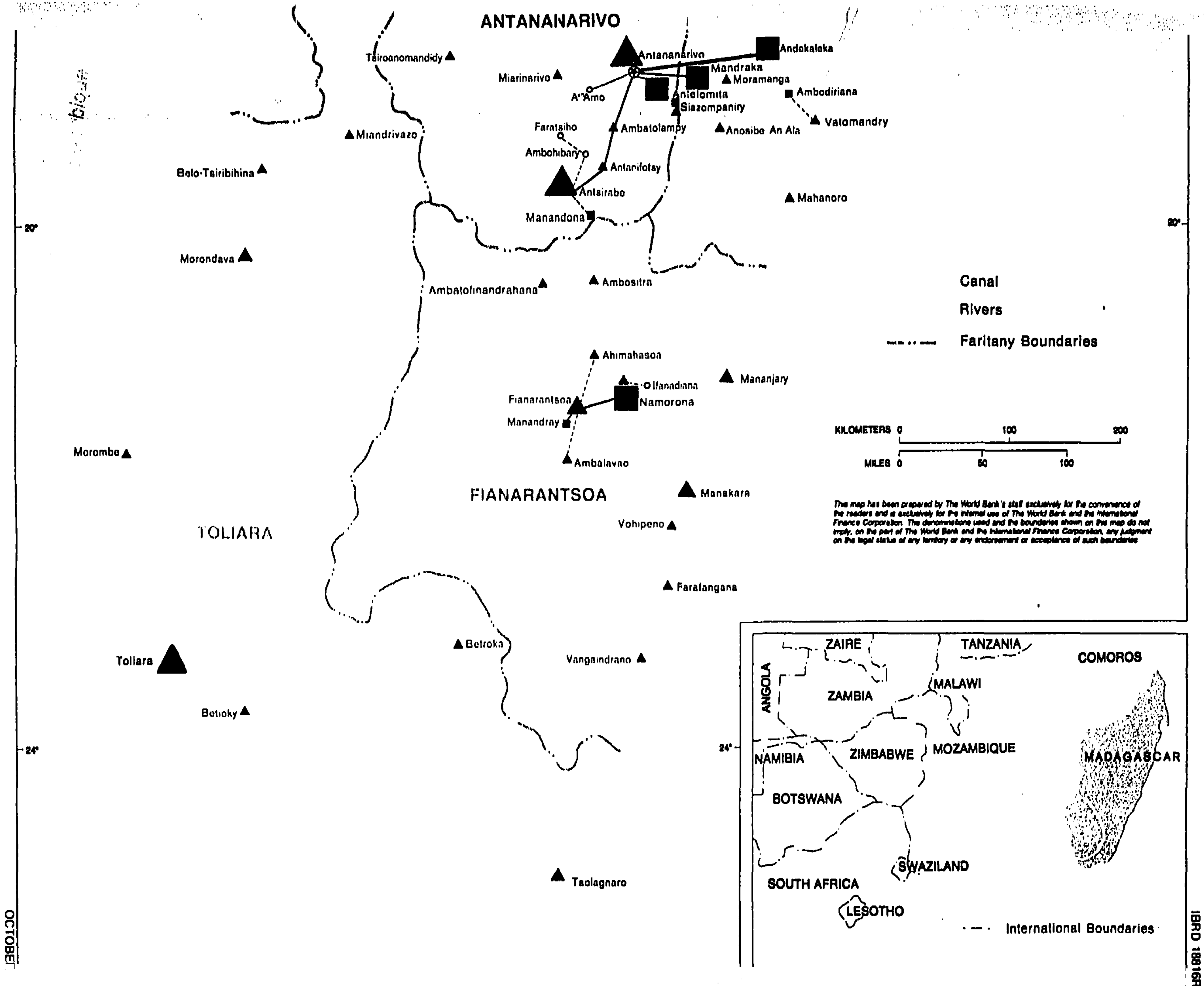


DECEMBER 1984

MADAGASCAR

PUBLIC POWER STATIONS AND TRANSMISSION LINES




ANTANANARIVO
Tsiroanomandidy
Antananarivo
Andekaleka
Mandraka
Moramanga
Miarinarivo
A'Amo
Antelomita
Siazompaniry
Ambodiriana
Vatomandry
Faratsiho
Ambatolampy
Anosibe An Ala
Miandrivazo
Ambohibary
Antanifotsy
Belo-Tsiribihina
Antsirabe
Mahanoro
Manandona
20°
Morondava
Ambatofinandrahana
Ambositra
Canal
Rivers
Faritany Boundaries
Ahimahasoa
Ifanadiana
Mananjary
Fianarantsoa
Namorona
Manandray
KILOMETERS 0 100 200
MILES 0 50 100
Morombe
Ambalavao
FIANARANTSOA
Manakara
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Vohipeno
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Farafangana
Betroka
Vangaindrano
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ZAIRE
TANZANIA
COMOROS
ANGOLA
MALAWI
ZAMBIA
Betioky
24°
NAMIBIA
ZIMBABWE
MOZAMBIQUE
MADAGASCAR
BOTSWANA
SWAZILAND
SOUTH AFRICA
Taolagnaro
LESOTHO
International Boundaries
OCTOBER
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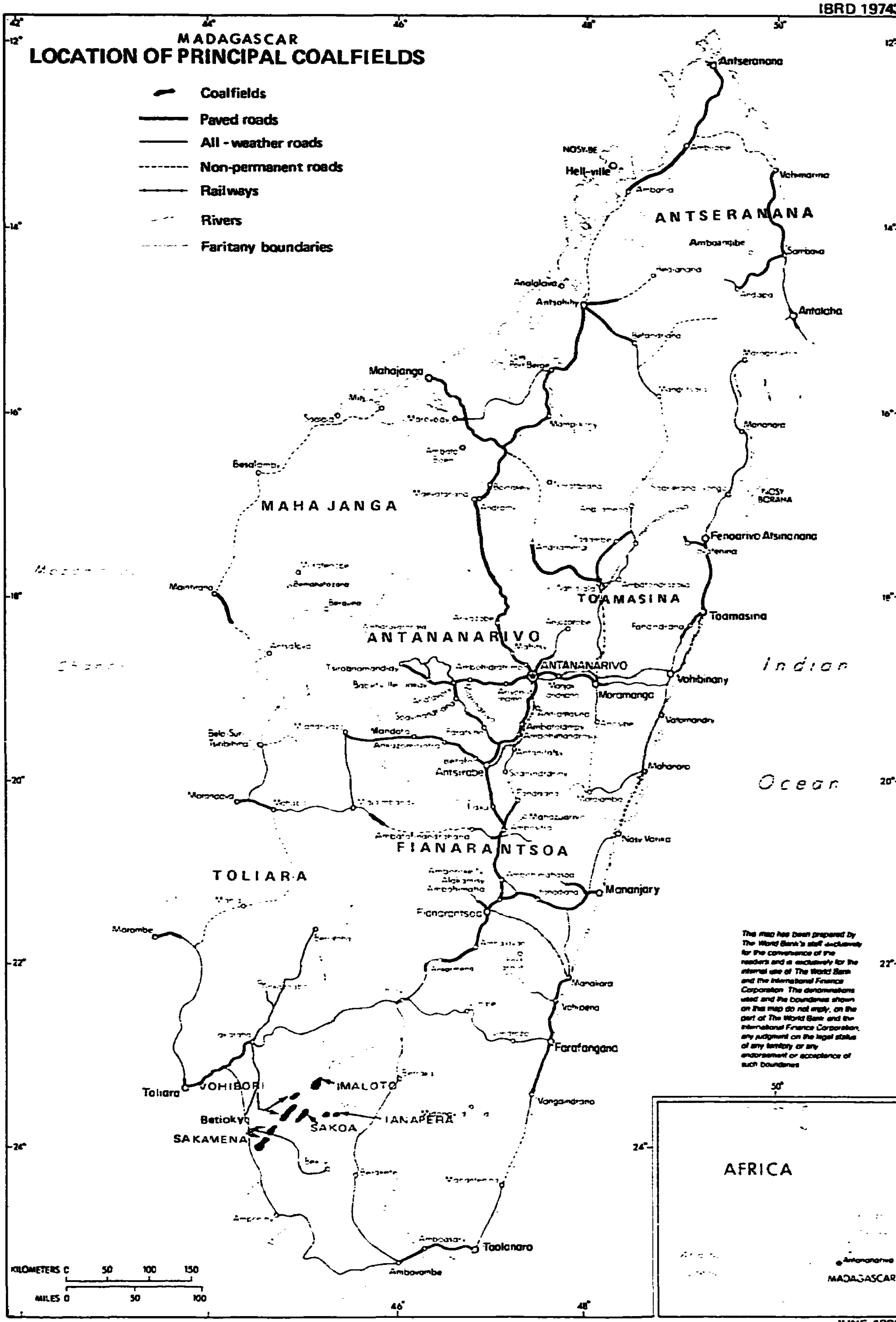

JUNE 1986