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ESMAP

Energy Sector Management Assistance Programme

Rwanda

Issues and Options in the Energy Sector

Report No. 8017-RW

JOINT UNDP/WORLD BANK

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

PURPOSE

The Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP) was launched in 1983 to complement the Energy Assessment Progamme which had been established three years earlier. An international Commission was convened in 1990 to address the creation of ESMAP's role in the Nineties. It concluded that the Programme had a crucial part to play over the next decade in assisting the developing countries to better manage their energy sectors given that the supply of energy at reasonable prices is a critical determinant of the pace and magnitude of the growth process. The Commission's recommendations received broad endorsement at the November 1990 ESMAP Annual Meeting. Today, ESMAP is carrying out energy assessments, preinvestment and prefeasibility activities and is providing institutional and policy advice. The program aims to strengthen the impact of bilateral and multilateral resources and private sector investment through providing technical assistance to the energy sector of developing countries. The findings and recommendations emerging from ESMAP activities provide governments, donors, and potential investors with the information needed to identify economically and environmentally sound energy projects and to accelerate their preparation and implementation.

ESMAP's operational activities are managed by two Divisions within the Industry and Energy Department at the World Bank and an ESMAP Secretariat.

- The Programme's activities are governed by the ESMAP Consultative Group which consists of its co-sponsors, the UNDP and the World Bank, the governments which provide financial support and representatives of the recipients of its assistance. The Chairman of the Group is the World Bank's Vice President, Sector Policy and Research. He is assisted by a Secretariat headed by the Group's Executive Secretary who is also responsible for relations with the donors and securing funding for the Programme's activities. The Secretariat also gives support and advice to a Technical Advisory Group of independent energy experts which meets periodically to review and scrutinize the Programme's strategic agenda, its work program and other issues related to ESMAP's functioning.

- The ESMAP Strategy and Programs Division is responsible for advising on which countries should receive ESMAP assistance, preparing relevant ESMAP programs of technical assistance to these countries and supports the Secretariat on funding issues. It also carries out broadly based studies such as energy assessments.

- The ESMAP Operations Division is responsible for the detailed design and implementation of tasks consisting mainly of sub-sectoral strategy formulation, preinvestment work, institutional studies, technical assistance and training within the framework of overall ESMAP country assistance programs.

FUNDING

The ESMAP represents a cooperative international effort supported by the World Bank, the United Nations Development Programme and other United Nations agencies, the European Community, Organization of American States (OAS), Latin American Energy Organization (OLADE), and a number of countries including Australia, Belgium, Canada, Denmark, Germany, Finland, France, Iceland, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, Switzerland, the United Kingdom and the United States.

FURTHER INFORMATION

For further information or copies of completed ESMAP reports, contact:

Office of the Director
Industry and Energy Department
The World Bank
1818 H Street N.W.
Washington, D.C. 20433
U.S.A.

OR

The Executive Secretary
ESMAP Consultative Group
The World Bank
1818 H Street, N.W.
Washington, D.C. 20433
U.S.A.

FOR OFFICIAL USE

Report No. 8017-RW

RWANDA

ISSUES AND OPTIONS IN THE ENERGY SECTOR

July 1991

This is one of a series of reports of the Joint UNDP/World Bank Energy Sector Management Programme. Finance for this work has been provided, in part, by the UNDP Energy Account, and the work has been carried out by the World Bank.

ABSTRACT

Rwanda has a fairly limited endowment of energy resources in the form of fuelwood, hydropower, and methane gas (the latter being still virtually undeveloped). With the present energy demand characteristics, population density and growth, and the landlocked position and topography of the country, the resources are either subject to depletion or are quite costly to produce and supply. A dominant share of energy (almost 90%) is supplied from biomass (woodfuels and crop residues) and households are the main consumers of energy (close to 90%). Approximately 80% of commercial energy is imported, preempting 35-40% of the country's foreign exchange earnings. Given the above profile, the principal direction of the country's efforts in the energy sector should be directed towards increasing the efficiency of production and utilization of energy, in order to minimize its cost to the economy and to reduce the imbalance between consumption and sustainable supply of woodfuels.

The main recommendations of the Report are that:

(i) the existing proposals for energy pricing and taxation policies for woodfuels be implemented, and the price level and structure for petroleum products and electricity be reviewed and subsequently adjusted, in order to give the users appropriate signals as to the economic cost of the energy they consume, taking also into consideration other objectives in the specific Rwandan context (financial, equity, fiscal, balance of payments);

(ii) the role of the Directorate of Energy concerning petroleum and household energy matters be expanded, (while at the same time acknowledging the role and responsibilities of ELECTROGAZ in the electricity subsector), by improving planning methodologies and the operations of energy supply institutions, and by relevant manpower development;

(iii) high priority be given to the preparation and implementation of studies and ongoing pilot projects (particularly related to woodfuels, but also in the petroleum and electricity subsectors) aimed at improving efficiency of energy production and end-uses;

(iv) the technical, economic and institutional prerequisites for commercial development of methane gas from Lake Kivu be established and a phased, least-cost development designed to attract private sector participation be adopted; and

(v) the completion of the Power Master Plan which under preparation be accelerated so that major generation investments be undertaken on the basis of that Plan.

ACRONYMS & ABBREVIATIONS

BUFMAR	Bureau des Formations Médicales Agréés du Rwanda
BUNEP	Société Nationale d'Etudes de Projets
CARE INTERNATIONAL	U.S. relief association
CCCE	The Caisse Centrale de Coopération Economique
CEAER	Centre d'Etudes et d'Applications de l'Energie au Rwanda
CEPGL	Communauté Economique des Pays des Grands Lacs
CNG	Compressed Natural Gas
CTS	Coopération Technique Suisse
DCS	Direction de la Conservation des Sols
DGE	Direction Générale de l'Energie
DGEau	Direction Générale de l'Eau
DGF	Direction Générale des Forêts
DGPA	Direction Générale de la Production Agricole
DGR	Direction du Génie Rural
DSE	Direction de la Santé et de l'Eau
DT	Direction des Transports
EAP	Environmental Action Plan
EBF	Economie de Bois de Feu
EDF	Electricité de France
EGL	Energie des Grands Lacs
ELECTROGAZ	The Etablissement Public de Production, de Transport et de Distribution d'Electricité, d'Eau et de Gaz
EPFL	Ecole Polytechnique Fédérale de Lausanne
ERP	Entreprise Rwandaise de Pétrole
FAC	Fonds d'Aide et de Coopération
FED	Fonds Européen de Développement
GTZ	Gesellschaft für Technische Zusammenarbeit
IDA	International Development Agency
IFP	Institut Français du Pétrole
INRS	Institut National de la Recherche Sociale
IPC	Interdisziplinäre Projekt Consult, GmbH
ISAR	Institut des Sciences Agronomiques au Rwanda
KFW	Kredietanstalt für Wiederaufban
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MINAGRI	Ministère de l'Agriculture, de l'Elevage et des Forêts
MINIFIN	Ministère des Finances
MINIFOPE	Ministère des Fonctions Publiques
MINIMART	Ministère de l'Industrie, des Mines et de l'Artisanat
MINIPLAN	Ministère du Plan
MINISAPASO	Ministère de la Santé Publique et des Affaires Sociales
MINITRANSCO	Ministère des Transports
MINITRAPE	Ministère des Travaux Publics, de l'Energie et de l'Eau
NES	National Environmental Strategy
OBK	Organisation pour l'Aménagement et le Développement du Bassin de la Rivière Kagera

OCIR	Office des Cultures Industrielles au Rwanda
ONAPO	Office National de la Population
ORTPN	Office Rwandais du Tourisme et des Parcs Naturels
PAP	Projet Agro-Pastoral
SINELAC	Société Nationale d'Electricité des Pays des Grands Lacs
SOCIGAZ	Société Internationale d'Exploitation, de Transport et de Commercialisation du Gaz Méthane du Lac Kivu
UNCDF	United Nations Capital Development Fund
UNDP	United Nations Development Programme
UNR	Université Nationale du Rwanda
USAID	United States Agency for International Development

CURRENCY EQUIVALENTS

Rwanda Franc (RF) = US$0.013 (June 1988)
Rwanda Franc 75 = US$1.00

MEASUREMENTS

Bbl	Barrel of oil	0.15899 cubic meter = 42 US gallons
BTU	British Termal Unit	0.252 kilocalories = 1.055 kJ
GWh	Gigawatt-hour	1,000,000 kilowatt-hours (kWh)
k	kilo	1,000
kcal	3.968 BTU	4.19 x 10^{-3}MJ
km	kilometer	1,000 meters; 0.62 miles
kV	kilovolt	1,000 volts
kWh	kilowatt hours	1,000 Watt hours
m^3	cubic meter	1.307 cubic yards
MJ	megajoules	10^{-3}GJ = 10^3kJ
mmBTU	million BTU	
MVA	megavolt ampere	1,000 kilowatt amperes
MW	megawatt	1,000 kilowatts; 1,000 kW
MWh	megawatt hour	1,000 kilowatt hours = 860,000 kcal = 0.248 TOE at 34% efficiency in thermal (oil) generation
TOE	Tons of Oil Equivalent	10.2 million kcal = 40.5 million BTU = 42.5 GJ
t	metric tons	1,000 kilograms; 2,204.6 pounds
lb	pound	
stère	eucalyptus wood	450 kg
"	pine wood	300 kg
$1m^3$	solid eucalyptus	900 kg
"	solid pine	750 kg
Nm^3	Normal Cubic meter	$1m^3$ at 0°Centigrade and at 1 atmosphere
l	liter	1.057 quarts (liquid)
HV	High voltage	
MV	Medium voltage	
LV	Low voltage	

ENERGY CONVERSION FACTORS

Fuel		GJ = 10^3MJ/unit	Physical Units/TOE
Liquid fuels (tons):	Crude oil	42.7	1.00
	LPG	45.2	0.94
	Kerosene	43.1	0.99
	Jet fuel	43.5	0.98
	Gasoline	44.0	0.97
	Gasoil	42.7	1.00
	Industrial diesel oil	42.3	1.01
	Fuel oil	41.0	1.04
Methane		33.5	
Electricity (MWh)		3.6 (per def.)	4.0
Fuelwood (ton)		16 a/	2.91
Charcoal (ton)		30 a/	1.46

a/ Air-dried wood, 15% moisture content wet basis (m.c.w.b.).

FISCAL YEAR

January 1 - December 31

This report is based on the findings of an energy assessment mission which visited Rwanda in June 1988. The mission comprised R. Broadfield (Mission Leader), T. Holtedahl (Report Coordinator), K. Mikitin (Power Sector Coordinator/Adviser), M. Patou (Consultant, Petroleum Specialist), L. Alston (Consultant, Power Engineer), P. Millan (Power Planner/Economist), P. Moulin (Consultant, Methane Gas Specialist), J.R. Mercier (Consultant, Household/Woodfuel Energy Specialist), P.R.S. Koulen (Consultant, New and Renewable Energy Specialist). R. van der Plas (Household Energy Specialist) assisted in editing the chapter on biomass/household energy.

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SUMMARY AND PRINCIPAL RECOMMENDATIONS

Introduction

1. The objectives of this assessment are to evaluate Rwanda's energy position, especially its energy resources and development options, and to suggest priorities among the actions that might be taken in the sector by the Government and external donors. The present report follows an energy assessment completed in 1982 (Report No. 3779 RW), and an activity completion report in 1984 (No. 017/84). Although the structure of the energy sector is basically the same as when the first assessment was carried out, the present evaluation is a self-contained review of the basic issues and options as seen nearly a decade later.

2. The main mission for this assessment took place in June 1988 and the draft report for the Government was completed in September 1989. Due to a variety of circumstances, discussions of the document with the Government were delayed. By the time these discussions took place in May/June 1991, Rwanda had embarked on an ambitious macro-economic and sector adjustment program. The report incorporates some of the recent developments. Although most of the data have not been updated, many of the issues remain the same. It was therefore decided to make the report available to a wider audience without further delays. A further update will be undertaken during the preparation of a possible World Bank energy sector credit for Rwanda in the near future.

Constraints to Energy Development

3. Rwanda is a small, low income, densely-populated, landlocked country, and its principal energy problems are related to these characteristics. Most Rwandans use wood and agricultural by-products for cooking and other basic energy needs. The high population density is making fuelwood increasingly scarce and puts reforestation efforts in competition for land with agricultural production. The country is dependent on overland transport routes crossing other countries for almost all of its imports, including oil. As a result, the country faces two main difficulties with respect to petroleum products: high costs and insecurity of supply. Since Rwanda's borders tend to follow major waterways, its major hydroelectric resources are found along its boundaries and thus their development requires international agreements. Rwanda's electric power grid is connected with those of Zaire and Burundi through two schemes from which all three countries draw power. The only known hydrocarbon resources are the large quantities of methane gas dissolved in the lower depths of Lake Kivu, which is shared by Rwanda and Zaire and which is virtually undeveloped.

4. The scarcity of technical and management skills affects the prospects for developing the country's energy resources, but it also reduces the scope for effective policy-making and the planning and operations of energy producing, marketing, and consuming institutions.

Energy Consumption

5. The energy situation in Rwanda is characterized by a high reliance on three sources of energy: woodfuels, agricultural by-products, and imported petroleum products. Firewood and charcoal combined meet more than 80% of the country's energy needs and the two other energy sources, close to 9% each. Hydropower, which dominates the public sector energy investment program, covers only around 1% of total energy requirements. Final energy consumption, totalling some 1.1 million TOE (tons of oil equivalent) or approximately 170 kgoe per capita is low, as is commercial energy consumption, at 16 kgoe per capita. This can be explained by the low level of income, by relatively high petroleum prices and high connection costs for electricity, by the dominance of subsistence agriculture in the economy and the small size of the industrial sector.

6. The consumption of commercial energy grew at an average annual rate of about 10% over the period 1980-87, i.e. around 10% for petroleum products and 9% per annum for electricity. Approximately 80% of commercial energy is imported and accounted for an average of 18% of merchandise imports during the period 1983-87. Per capita consumption of electricity was 16 kWh in 1987, one of the lowest levels in Sub-Saharan Africa.

FINAL ENERGY CONSUMPTION, 1987

	Thousand TOE	Percent
Fuelwood	874.0	78.7
Agricultural by-products	100.0	9.0
Charcoal	30.4	2.7
Peat	0.5	0.0
Petroleum products	97.4	8.8
Electricity	8.9	0.8
Total	1,111.2	100.0

Source: see Table 1.2.

Energy Resources

7. Rwanda appears to have a certain, but fairly limited, endowment of energy resources (primarily fuelwood, hydro-power, and methane gas) but with the present demand characteristics, population density and increase, and the landlocked position and topography of the country, the resources are either under the pressure of potential depletion or are relatively costly to produce and supply.

8. Woodfuels and crop residues. The tree cover totals some 665,000 ha or 25% of the country's total land area. This includes natural forests with savannahs (the bulk), forest domains, village and private plantations, as well as scattered farm trees. An estimated 95% of wood production is for domestic energy consumption in the form of fuelwood and charcoal. Some 85% of woodfuels is used directly as firewood, the rest being converted to charcoal. Data related to forestry and woodfuels are poor but the country is probably depleting its forest resources on a national level, and for certain areas there are quite significant imbalances between wood consumption and sustainable supply. High

population density and dependence on woodfuels for energy needs are determining factors. Charcoal, which is resource-intensive in production as well as in use, is to a significant extent responsible for the deforestation that has taken place in certain parts of the country.

9. Peat and Papyrus. For peat, estimates vary significantly, but proven reserves are at a minimum 5 million tons. Papyrus swamps cover some 23,000 ha of land. Due to their relative abundance, both peat and papyrus are being investigated as possible substitute fuels for the industrial and household sectors. The viability of these resources as fuels on any significant scale is at present highly uncertain for a variety of reasons, however, including the extent and the location of the resources in relation to main centers of consumption, cost of production and transportation, their practicality in use, and the potential environmental damage from large-scale exploitation.

10. Hydropower. Because of mountainous terrain and abundant rainfall (1,250-1,500 mm/year), there should be a significant potential for generation of electricity by small hydroelectric generating stations in the numerous, steep, fast-flowing rivers and streams. However, these sites are costly to develop because of the small capacity and the topography which prevents the construction of reservoirs to store water from the high flow seasons for use during the dry seasons. Total hydro-power potential is estimated to be about 150 MW. Present domestic grid-connected generating facilities include four hydroelectric plants with a total installed capacity of 26.5 MW (plus four diesel plants with total power of 3.6 MW on standby or out of service). Rwanda has imported power since 1977 from Zaire's Ruzizi I plant but in a steadily decreasing proportion to total energy supplied to the network (1987: 15%). Contractual arrangements with Zaire allow Rwanda to import about double the energy taken in 1987, but the country has preferred to maximize the use of its domestic power plants, a policy which over time has had a negative effect on its hydrological resources (lake levels). Beginning in 1989, the operation of the Ruzizi II plant, of which Rwanda owns one third has reduced import requirements, which will be further reduced by the installation of the plant's third 13.3 MW unit around 1995. Least cost power generation development is, pending the outcome of a planned power master plan study by the end of '92, most likely to be related to regional projects for regional markets.

11. Hydrocarbons. The country has no proven crude oil reserves and all liquid fuel products have to be imported at high costs. Together with Zaire, however, Rwanda has a unique energy (and petrochemical feedstock) resource in the form of methane gas dissolved in the deep waters of Lake Kivu which straddles the border of the two countries Recoverable reserves amount to some 50 billion Nm^3, equivalent to about 40 million TOE. A pilot extraction plant was built in 1963. A series of studies on technical, safety and economic aspects have been carried out and clearly indicate the possibility of producing gas for use as a fuel, but present estimated development costs are high. Further studies based on better adapted technologies and small scale operations are still required to firmly establish the real potential of the gas as an energy resource for Rwanda, at a competitive cost and on any significant scale.

12. New and renewable sources of energy. Despite a relatively promising environment and high conventional energy costs, new and renewable energy technologies have had limited application and alternative energy sources are not likely to provide substitutes for traditional or modern energy sources on any significant scale in the mid-term future. Most options are non-economic at present day

technologies and international energy prices. Photo-voltaic and micro-hydro systems would appear, however, to offer a limited potential in isolated areas.

Government Energy Strategy and Policies

13. In the face of the energy resource constraints, the Government's declared energy policy places emphasis on: (i) energy self-sufficiency; (ii) regeneration and expansion of the potential for fuelwood production; (iii) improved efficiency in the production of charcoal and the use of woodfuels; (iv) identification of alternative competitive sources of energy such as peat, biogaz, etc.; and (v) extending electricity supplies to rural areas and to cottage industries, and a policy of affordable tariffs. As shown by major increases in electricity prices in 1991, the Government is paying increasing attention to appropriate energy pricing, expressing the economic cost of supply and constituting the most important policy instrument for effective demand management.

14. Present prices of firewood and charcoal do not reflect economic costs, and efficiency in the use of woodfuels and the production of charcoal is not promoted under the present system. Prices of both fuels are basically market-determined. The Government intervenes by setting a stumpage fee for wood originating in public forests, but the official price is hardly ever enforced, most of the transactions taking place at much lower prices. The market prices for wood are also below the cost of wood from most types of plantations reflecting, inter alia, low purchasing power of consumers relying on fuelwood for cooking, limited markets for commercial fuelwood as well as for higher value uses of wood, and supply from sources where the total cost of the wood is not fully perceived by the supplier.

15. Electricity tariffs in effect until June 1991 were approved in January 1988, replacing tariff that had existed since 1981. The rate change in 1988 represented an average decrease of 14% instead of the increase of 15% recommended by consultants, who examined primarily the financial need for rate adjustment. That change put rates for low voltage users at about 40% below their estimated economic cost, while medium voltage users pay a price closer to the real cost. There are no lifeline rates for low-income consumers and the connection charges are very high. Thus, the level is too low both in economic terms and for the utility to meet its financial objectives, and at the same time lacks a deliberate social profile. The Government has decided to gradually remedy this situation. As a first step, it has announced that in July '91 tariffs will be increased by 50%.

16. The prices of petroleum products are only partly controlled by the Government: for gasoline and automotive diesel a maximum selling price is set but for other products prices are not controlled. The Government's petroleum price policy is to keep the selling price of the main products constant in nominal terms while adapting the level of taxation to account for changes in the CIF cost. Maximum prices had not changed since 1981 and therefore still reflect record level international market prices at the official exchange rate (but in real terms, they are reduced by inflation and the over-valuation of the Rwanda Franc). In November 1990, following the devaluation of the Rwanda Franc, petroleum prices were raised considerably (the new price of gasoline is now approximately US$1 per liter). Import duties and taxation vary considerably for different types of products, being relatively high for gasoline and diesel, and low for kerosene and fuel oil. There are several indications that the present taxation and

price structure/level may not be optimal from an efficiency point of view, nor from financial, equity and other considerations: they have been the main elements behind rapidly increasing consumption, clandestine imports from neighboring countries, possible unwanted substitution effects, and high wholesaler margins on products that are less heavily taxed.

17. Institutional Issues. The Directorate of Energy in MINITRAPE (Ministère des Travaux Publics et de l'Energie) has the lead role in formulating sector policy and development strategy, preparing and applying energy legislation, executing studies, supervising projects, and maintaining sector statistics. The Directorate's knowledge of the energy sector is incomplete, however, as it does not monitor--nor is involved in strategic issues related to--the petroleum sector. Furthermore, no one government institution has an in-depth understanding of both fuelwood supply and demand questions, which reduces the possibilities of applying an integrated approach to woodfuel efficiency and substitution issues, as well as to overall energy sector issues, in view of the dominating role of woodfuels in the energy picture. Projects to be retained in the country's development plan are selected on the basis of their coherence with both national and sector objectives. At present, however, economic viability is not given sufficient weight in project selection, which means that decisions in the energy sector may easily be suboptimal. This reflects, inter alia, the lack of economists and financial experts in the Directorate and the need for key personnel to receive training to improve analytical skills and understanding of generally accepted project analysis methodologies and energy planning issues. More fundamentally, however, it likely can be explained by generous support among donors. Finally, at the energy sector and subsector levels, the environmental impacts associated with energy development need to be institutionalized and systematically integrated into the evaluation of production and use of energy. These impacts relate in particular to fuelwood, charcoal and methane gas from Lake Kivu.

18. On a subsector level, the main shortcomings are related to:

(a) in the biomass and household energy subsector:

(i) the previously indicated gaps in the management of woodfuels issues and the household energy area and the need for better coordination of donor activities related to programs and projects in these areas;

(ii) the uncertainties concerning data on traditional fuels hampering efficient planning and implementation of rural energy supply and conservation measures;

(iii) the shortage of forestry engineers and technicians;

(b) in the petroleum subsector:

(i) a situation where the Government's petroleum policy is formulated and implemented with little or no involvement from the institutions dealing with energy matters;

(ii) the system of authorized carriers with a tank fleet for transport of petroleum products from or through neighboring countries and the policy of regulated transport tariffs, both of which lead to inefficiencies and higher costs;

(iii) the limitations related to the present system of monitoring oil prices on the international market;

(iv) the lack of a contingency plan to deal with potential supply interruptions in petroleum products;

(v) the unresolved technical, economic/financial, and legal/institutional issues related to the viability of developing the Lake Kivu methane gas on a scale reflecting the potential of the resource and the energy requirements of the country;

(c) in the power subsector:

(i) the lack of criteria for assessing the economic cost of self-reliance with respect to electric power generation versus regional imports, including the cost of lower lake levels by operating domestic power plants above their rated capacity. This will be largely corrected by a Power Master Plan which is under preparation to serve as a basis for a least cost investment plan for the subsector;

(ii) the shortcomings with respect to analysis and evaluation of rural electrification projects leading to uneconomic network extensions;

(iii) the limited operational and financial autonomy or commercial profile of the electricity utility, ELECTROGAZ, and its limited involvement in aspects related to planning and execution of investments for generation and transmission;

(iv) the limited number of qualified technical staff in ELECTROGAZ, especially in the areas of planning and maintenance.

Energy Investment

19. Public investments in the energy sector have in the past been dominated by projects in the power subsector and this situation is expected to remain. In the absence of results of the Power Master Plan study, MINITRAPE has prepared an interim investment plan for the power subsector totalling US$ 227 million (1987 prices) mainly for the period 1989-93, reflecting two governmental objectives: independence from power imports, and extension of the network to rural areas. Without the outcome of the Master Plan, particularly its rigorously established demand projections and price analysis, decisions can easily be made that are sub-optimal. Careful selection of investments is also necessary because of resource constraints. The investment plan shows that the most cost-effective new source of supply for Rwanda is the installation of the third unit of Ruzizi II. Demand projections show that it is

unlikely that any new generation capacity will be needed before 1995 if Rwanda takes advantage of the surplus power in the regional interconnected network. Early completion of the Master Plan will still allow sufficient time to optimize investments for the demand beyond 1995.

Main Recommendations

20. Since Rwanda's endowment of energy resources is limited and costly to develop, the main direction of the country's efforts in the energy sector should be to increase the efficiency of production and utilization of energy so as to keep the costs of energy to the economy in check and to reduce the imbalance between consumption and sustainable supply of woodfuels. At the institutional level, this requires strengthening the capabilities of MINITRAPE and more specifically its Energy Directorate, and of ELECTROGAZ, the public power, water and gas utility. The strategy also would apply to the Forestry Department of the Ministry of Agriculture, which is concerned with the supply of woodfuel resources. At the resource level, it would entail protecting the existing sources of woodfuels and attempting to increase the sustainable supply, as well as increasing end-use efficiency of energy resources in general. It would also involve determined efforts to substitute energy imports wherever economically feasible, possibly through developing the methane gas reserve in Lake Kivu.

21. The most pressing issues which the Rwandan authorities should address concern policies, studies and institutions. Public investments are relevant mainly in the areas of electric power and (possibly) methane gas development, but their scope and timing depend on the outcome of studies yet to be completed.

Policies and Institutional Measures

22. The Government should review or implement already reviewed energy pricing policies in all main subsectors. It is important to identify interfuel substitution options and consider closely the potential effects, including environmental impacts, of specific recommendations.

(a) On woodfuels, the Government should implement the fuelwood price policy proposed by the Forestry Directorate. This proposal implies replacing the present uniform stumpage fee of RF 400/stère by a range of prices from RF 150-700/stère, depending on tree category and location of plantations. The proposal has been reviewed by the World Bank in the course of its Second Integrated Forestry Project with certain modifications (e.g., increasing the allowance for transport costs). Furthermore, the dual charcoal taxation proposal in the form of a tax on marketed charcoal should be adopted: this tax would be lower for, and should thereby encourage the use of, improved carbonization techniques. The objective is also to increase end-use efficiency and augment the revenues of the rural communes. The implementation of the proposals needs to be accompanied by awareness and publicity campaigns, and by the strengthening of the Forestry Directorate to improve enforcement.

(b) For petroleum products, a study should be carried out on taxation and pricing, giving due consideration to the economic cost both in absolute and relative terms. The level and structure should be reviewed given the impact of exchange rate adjustments and the need to: (a) limit inefficient consumption of imported products for economic, especially balance of payments, reasons; (b) reduce clandestine imports from neighboring countries; (c) consider the fiscal revenue potential of petroleum taxes; (d) consider substitution effects between petroleum products and vis-à-vis other fuel sources (e.g., wood and deforestation aspects); and (e) evaluate to which extent intended beneficiaries actually derive the advantage of lower taxes (e.g., on kerosene). Without necessarily awaiting the results of the petroleum pricing study, the Government should deregulate the transportation tariffs for petroleum products from neighboring countries, in order to spur efficiency and lower costs. A comprehensive approach to the pricing and taxation issue would call for collaboration between the Energy Directorate and the agencies responsible for macro-economic decision making.

(c) On electricity, the tariff structure should be amended to better reflect the economic costs of supply for each category of service and eliminate consumer subsidies. Equity considerations and the financial needs of a restructured, autonomous public utility should also be reflected in the new tariff structure. Subsidized tariffs should not be used as part of a policy of promoting conversion of industrial boilers to electricity in cases where the conversions are not warranted on economic grounds. Long run marginal costs (1990 figures, before devaluation) have been preliminarily estimated at US$0.15/kWh for medium voltage consumption (the present average tariff is US$0.13 and US$0.10 for capacities below and above 100 kW, respectively) and US$0.18/kWh for low voltage consumption (the present low voltage rate is US$0.11). The above calculations were carried out prior to the recent macro-economic adjustments, and would need to be updated. More rigorously established figures will, in any case, result from the forthcoming Power Master Plan.

23. Other policy recommendations are as follows:

The petroleum subsector

(a) The transport system should be deregulated by abolishing the practice of authorized carriers for the international transportation of petroleum products.

(b) A contingency plan for the utilization and replenishment of petroleum buffer stocks in case of possible interruptions in surface transportation should be developed, and a policy should be defined for financing not only the petroleum products to be stored in the recently completed depots but also future extensions of the buffer stocks.

The electric power subsector

(a) A rural electrification policy should be developed that weighs all least cost supply options and ensures that all projects and extensions are justified on a case by case basis by systematic and rigorous socio-economic evaluations.

(b) Lower-cost design standards for power distribution should be adopted. Donors should be approached to fund pilot low-cost distribution schemes to test the appropriateness and viability of such an approach. Related to this is the need to adopt a new policy of connection charges which spreads over time the initial cost of connection borne by the consumer.

Energy and Environment

The National Environment Strategy and the Environmental Action Plan which the Government has decided to prepare will produce guidelines for environmental protection and environmental management. These guidelines should be adopted in all matters related to energy development to ensure that environmental impacts are systematically taken into consideration as part of project preparations. This has particular relevance in the case of forest exploitation, hydropower projects, peat and papyrus exploitation, and methane gas extraction and transportation from Lake Kivu. To put this into effect, the Government should consider assigning the responsibility for this to the Planning Unit within the Directorate of Energy and identify training requirements. Close liaison will be needed with the institution which will have the overall responsibility for environmental protection and management.

24. Institutions

(a) The Government should strengthen its ability to set and supervise energy policies, to develop adequate information and skills for the analysis of interfuel substitution possibilities, and to prepare and analyze energy projects by:

(i) instituting comprehensive sector planning and monitoring in the Directorate of Energy of MINITRAPE (concentrating on non-electricity subsectors), the responsibility of which should be expanded to cover: (a) the formulation and follow-up of petroleum policy and closer monitoring of the development in the international and national petroleum markets, in cooperation with the other ministries concerned, and (b) the monitoring of household energy issues, in cooperation with the Forestry Department; as an alternative to creating a new unit, the New and Renewable Energy Division within DGE should be strengthened and given the additional responsibility of monitoring household energy matters, making policy proposals, initiating and supervising projects, and coordinating donor activities;

(ii) instituting a more rigorous approach to the selection of energy projects by subjecting them to generally acknowledged tests of economic and financial viability;

(iii) developing the analytical skills of key personnel in the Directorate of Energy through training in energy planning and project analysis, and recruiting economists and financial specialists to supplement mainly technically oriented staff.

(b) Assistance, initiated under Swiss Cooperation, to strengthen the Directorate of Forestry should be continued and expanded by increasing the number of qualified forestry staff in order that DGF may respond to the challenges in the traditional energy subsector, such as the implementation of large scale forestry development and conservation policy, and by developing the skills necessary for implementing the pricing and taxation reforms related to woodfuels mentioned earlier.

(c) ELECTROGAZ should:

(i) be restructured as a self-reliant public utility which can renew, expand, maintain, and operate its installations according to the national socio-economic framework established by the Government of Rwanda and the objectives established in the "Contract Plan" which will be signed between Electrogaz and the Government of Rwanda. Electrogaz should achieve commercial and financial performance objectives in accordance with commonly accepted utility practice and as outlined in the "Contract Plan", including managing separate financial and commercial accounts for its electricity, water and gas operations;

(ii) take over the responsibility from MINITRAPE for planning and implementation within the subsector (including generation and transmission projects); and

(iii) prepare a human resource development plan aimed at filling the more immediate staff needs, e.g., for maintenance, but also at providing the utility with adequate competent staff as a restructured enterprise.

(d) Together with the Zairian authorities and with the assistance of legal experts, the Government should determine the legal and institutional framework necessary for promoting the methane gas resource in Lake Kivu. Decisions in this area will be closely related to the outcome of further studies of technical, market and economic aspects. The World Bank may provide technical assistance to the two Governments to determine possible future courses of action.

25. Studies and Pilot Projects

The biomass and household energy subsector.

(a) A national survey of the supply and demand of traditional fuels should be conducted to enable the authorities to obtain a firmer basis for planning rural energy supply and conservation measures.

(b) The ongoing household energy pilot projects on improved charcoal stoves and charcoal production techniques should be continued. For the stoves project, this would mean, inter alia, commence testing efficiency under real life conditions and proceed with commercialization; for the improved carbonization methods, training of more charcoalers is needed to spread the benefits of efficiency improvements that have been demonstrated.

(c) In conjunction with the present production research on papyrus briquettes, a concise socio-economic evaluation should be conducted to ascertain the viability of papyrus briquettes as a household fuel.

The petroleum subsector

(a) The Government should carefully consider the future recommendations of a study, managed by the World Bank, on optimizing the supply of petroleum products in Sub-Saharan Africa subregions, as an alternative to the present practice of independent purchases in small quantities.

(b) Based on the potential for improving the end-use efficiency of fuel consumption (particularly fuel oil and diesel) which has been identified in a study on industrial energy use in Rwanda, the Government should support advisory assistance and encourage the installation of metering and automatic regulation devices. For the longer term, less fuel-consuming industrial processes should be considered (e.g., for cement production).

(c) Regarding future development of methane gas in Lake Kivu, studies should be continued with the objective of identifying more cost-effective methods of gas production and transport, adapted to the context of Lake Kivu and the potential energy markets in Rwanda and Zaire. Finally, the basic approach to the process of developing the resource must be addressed and decided upon, e.g. a phased development based on a promotion concept.

The electricity subsector

(a) The Government should proceed expeditiously with the planned Power Master Plan study, in order to have a firm basis for decisions with respect to future investments in the subsector and for adjusting power tariffs; the study should also consider a generation option based on methane gas from Lake Kivu.

(b) The distribution network should be inventoried in all key population centers to serve as the basis for the distribution rehabilitation plan which should result from the Power Master Plan study.

(c) Network operating rules, based on systematic collection and analyses of operating statistics by ELECTROGAZ, should be defined for normal and non-normal conditions. The rules would need to give special attention to the issue of hydrological resource management and tradeoffs in the use of energy from domestic versus regional resources.

(d) Proper attention should be given by the Government and donors to supervision of rehabilitation and construction projects, to avoid past experience of technical deficiencies and equipment deterioration.

26. Investments

(a) Electricity

(i) While awaiting the Power Master Plan, new investments should be limited to expanding connections in areas where service is already available. The expected least-cost source of new supply is the third unit of Ruzizi II.

(ii) To eliminate the risk of a major network blackout, a spare transformer and other equipment should be purchased.

(b) Petroleum

Filling of the recently completed 15,000 m^3 storage tank would imply purchases of petroleum products of approximately US$ 5 million, for which financing remains to be found. Consideration should be given to covering the cost of the tied capital through a tax, to be considered in conjunction with the revision of the petroleum taxation and pricing system.

(c) Methane gas

(i) A quadrupling of the net production capacity (or quintupling gross production capacity) of the onshore Cap Rubona pilot plant is being studied with the objective of fully meeting the fuel requirements of a neighboring brewery. The project will be Belgian-financed and is expected to cost US$13 million.

(ii) Should the technical, economic, and institutional prerequisites for full commercial development of the Lake gas prove to be present, large investments in production, conversion, distribution facilities, the size of which remains to be determined would be required.

(d) Biomass

Investments in fuelwood projects are uncertain and are related to plantations which serve as sources of wood for various purposes. Investments in peat and papyrus projects depend on the outcome of further studies and investigations.

I. ENERGY AND THE ECONOMY

Background

1.1 Rwanda is a small, landlocked and densely-populated country covering some 26,000 square kilometers on mountainous land. Reflecting its landlocked location, the country is dependent on lengthy trade routes through two countries to the Indian Ocean. With a total population estimated at about 7.5 million, increasing at an annual rate of 3.7 percent, Rwanda is one of the most densely populated countries in Africa (290 people per km^2). The country is populated by two ethnic groups: the majority Hutus, which constitute some 85 percent of the population, and the Tutsis, which ruled the country before independence in 1960. Intense conflicts led to the massive exile of Tutsis in 1959, but the two groups have coexisted relatively peacefully until an invasion by exiled Tutsis in October 1990. Diplomatic efforts with neighboring countries to find a political solution to the conflict and President Habyarimana's decision to initiate a process of national reconciliation and to invite all Rwandese to join efforts in the country's reconstruction led to a formal cease-fire, which was signed on March 29, 1991.

1.2 Rwanda's economy is concentrated, with about 45 percent of GDP and 80 percent of exports accounted for by coffee and tea. Some 95 percent of the population lives in rural areas and derives its livelihood from subsistence agriculture and the cultivation of coffee and tea. Agriculture accounts for almost one half of total output, and for the employment of some 90 percent of the active labor force. The industrial sector, apart from some agro-industrial activities, remains small and insufficiently diversified, in spite of Government efforts to expand the manufacturing base by pursuing an active import-substitution strategy. After years of contraction in mining sector activity, the mining of tin, the principal product, stopped in 1987.

1.3 In the 1960s and 1970s, economic performance was considerably better than that of other countries in Sub-Saharan Africa, although below the performance of low-income countries as a whole. During the 1973-80 period, Rwanda experienced relatively high per-capita income growth of about 2.2 percent a year, compared to 0.1 percent for Sub-Saharan Africa as a whole. Per capita income in 1980-87 declined by 1 percent per year, but the comparable figure for Sub-Saharan Africa was three times worse (Table 1.1). Growth was achieved under conditions of relative financial stability. Prudent economic management in the 1970s enabled the country to achieve surpluses in the budget, a favorable position of external reserves, and a low debt-service ratio. Throughout the 1970s and early 1980s, the Government followed a relatively non-interventionist economic policy, and the trade regime was one of the more liberal in the region.

1.4 Beginning in the early 1980s, however, the economy started showing signs of stress, arising from both an unfavorable evolution of the terms of trade and insufficient domestic policy adjustments. The coffee boom of the late 1970s was not perceived by the Rwandese authorities as a temporary phenomenon, and the Government embarked on a large expenditure program. As a result, the economy was in a vulnerable position when in 1980-81 coffee prices returned to trend levels, and the external terms of trade declined by more than one third. In response to emerging financial imbalances, the Government adopted restrictive fiscal and monetary policies which have been pursued since then. At the same time, it increased its level of intervention in the economy. Beginning in 1983, for instance, price controls were applied to prevent prices of imported goods from rising excessively as a result of tightened import licensing. Moreover, inefficient industrial enterprises were protected through the imposition of "temporary" import prohibitions on competing imports. By the mid-1980s, the fiscal and financial situation had improved somewhat, but economic growth had been erratic.

Recent Macroeconomic Developments

1.5 Since early 1987, Rwanda has been faced with precipitous declines in world coffee prices and unfavorable climatic conditions which had an adverse impact on agricultural production. Read GDP stagnated in 1987 and 1988 and declined sharply in 1989 by 6.6 percent, with the result that real income per capita dropped by almost 16.5 percent from that attained in 1986. The annual inflation rate as measured by the consumer price index has been relatively low (on average 2.7 percent since 1986), in part because of the overvalued exchange rate, the pervasive nature of price controls, and the permeability of Rwanda's borders.

1.6 Rwanda's balance of payments situation has been precarious since 1986, and the current account deficit reached the equivalent of 11 percent of GDP in 1989, despite sharply curtailed imports during the last three years. The deterioration in the export performance cannot be explained solely by the fall in world coffee prices: coffee exports have been declining in both quantity and quality, while non-coffee export performance has been mediocre, largely because of an overvalued exchange rate, low productivity, and excessive regulations and controls. The overvaluation of the exchange rate was one of the main factors prompting the closure of virtually all mining activities, which had provided around 15 percent of exports at the beginning of the eighties.

1.7 At the same time, restraint on growth of government expenditure did not reduce the fiscal deficit to a sustainable level. The burden on government finances of exporting coffee at a loss became increasingly onerous: during 1987-1989, average annual transfers to coffee producers accounted for 10 percent of total current outlays. On the revenue side, the tax base is narrow with strong reliance on trade and a few sales taxes. Although the fiscal deficit (excluding grants) as a percentage of GDP has declined since the record level of 10.4 percent in 1987, it was still estimated at about 7.6 percent in 1989, and its financing required considerable recourse to local borrowing. The rising domestic debt burden became an increasingly important drain on public resources.

1.8 This marked deterioration in the overall economic climate and performance has exacerbated structural problems of the economy. Rapid population growth has resulted in increasingly fragmented farms and declining soil fertility, and there is growing evidence that structural food deficits have emerged. Furthermore, the economy has been unable to provide productive employment to new entrants into the labor force and displaced workers from the agricultural sector.

The Macroeconomic Reform Program

1.9 To address the problems discussed above, the Government began implementing in November 1990 a macroeconomic reform program designed with the assistance of the World Bank and the International Monetary Fund. The program, which is outlined in a Policy Framework Paper, stresses a stronger reliance on market forces and the private sector, as well as a more export-oriented approach. The key macroeconomic objectives of the program are to restore economic growth to about 4 percent and to contain the annual inflation rate to 5 percent by 1993, while at the same time reaching a sustainable budgetary and balance of payments situation. To achieve these objectives, the program aims at fostering an environment conducive to private sector activity and international competitiveness; improving and rationalizing public resource management; laying the foundation for developing the human resource base and improving the management of natural resources.

1.10 To improve Rwanda's international competitiveness, the Government devalued the Rwanda Franc by 40 percent in foreign exchange terms in November 1990 and plans to pursue a flexible exchange rate policy in the future. To promote private sector involvement in the economy, the Government proposes to liberalize foreign exchange allocation and the trade regime, eliminate price controls and export taxes, set up new administrative procedures for enterprise creation which are transparent, and begin the liberalization of the financial system. A coherent monetary policy which ensures stability, and the development of a responsive and efficient financial system is a necessary complement to the reforms in the real economy.

Energy and the Commercial Balance

1.11 Energy demand in Rwanda is basically met by four fuels: woodfuels, agricultural by-products, petroleum products, and electricity. All refined petroleum products are imported from, or through, neighboring countries. Electricity, almost entirely from hydro sources, originates mainly from domestic plants which, in 1987, accounted for 85% of the power supplied, the remainder being imported from Zaire.

1.12 Imports of energy, almost entirely comprised of petroleum products, are an important element of Rwanda's commercial balance. For the 1983-87 period, energy imports accounted for an average of 18% of annual merchandise imports and absorbed nearly 40% of receipts from merchandise exports (see Table 1.1). Imports of electricity for the same period averaged less than 0.2% of the total merchandise imports. In spite of quite significant increases in the quantity of petroleum products consumed, both the absolute value of petroleum product imports and their relative importance vis-à-vis other imports have decreased since 1985. This trend can be attributed in part to the decrease in the world market price of petroleum products, but more significantly to the appreciation of the Rwanda Franc against the US Dollar.

Table 1.1: ENERGY AND THE COMMERCIAL BALANCE, 1983-87
(RF current millions)

	1983	1984	1985	1986	1987 a/
Imports of Petroleum Products	4,816	5,005	5,217	5,014	4,339
Imports of Electricity	34	30	57	54	52
Total Energy Imports	4,850	5,035	5,274	5,068	4,391
Merchandise Imports (CIF)	26,943	27,240	30,073	30,625	27,754
Merchandise Exports (FOB)	11,706	14,286	12,769	16,138	9,675
Imports of Energy as % of Total Imports	19.4	8.5	17.5	16.5	15.8
Imports of Energy as % of Total Exports	41.4	35.2	41.3	31.4	45.0
RF/US$ (period average)	94.3	100.2	101.3	87.6	79.7

a/ Preliminary estimates.

Source: IMF and mission estimates.

1.13 Concerns for the balance of payments and a desire to reduce the country's dependence on imports in the interest of national security have contributed to efforts on the part of the Government to limit the fuel import bill. These concerns are reflected in the generally high import duties and taxes on petroleum products, and in the development of domestic hydroelectric resources despite the availability of low-cost power import alternatives.

Energy Supply and Consumption Patterns

1.14 Rwanda's principal energy resource is its forest, which is being depleted for firewood and its by-product: charcoal. Agricultural by-products play an important role for household energy needs. Peat is available in some areas but is not widely used. The potential for development of hydroelectric power exists but development is costly due to the sites having low capacity and being widely scattered. The best hydro sources are in the rivers Kagera and Ruzizi. There is no evidence of the presence of oil in the country but there is a unique potential source of methane gas in the deep waters of Lake Kivu. Although coal is found in neighboring Zaire, none has been located in Rwanda. In terms of new and renewable sources of energy, solar energy may have a certain potential.

1.15 In 1987, Rwanda's final energy consumption totalled about 1,1 million tons of oil equivalent (TOE) of which 90% was in the form of fuelwood, charcoal, agricultural by-products, and the balance was provided by imported petroleum products, hydroelectricity, and a small quantity of methane gas (see Table 1.2). The largest consuming subsector was households (88%), followed by transport (7%), industry (4%), and services (1%). Final energy consumption per capita was 168 kgoe.

Table 1.2: RWANDA - ENERGY BALANCE, 1987
(in '000s of TOE)

	Fuelwood	Agri. by-prod.	Charcoal	Peat	Gasoline	Kerosene	Diesel	Fuel oil	LPG	Methane gas	Elec-tricity	Total	Per cent
GROSS SUPPLY													
Domestic primary production	1,026.3	100.0		0.5						1.0	27.1	1,154.9	
Imports					39.7 b/	13.5	37.3 b/	11.3	0.2		4.7	106.7	
Total available	1,026.3	100.0		0.5	39.7	13.5	37.3	11.3	0.2	1.0	31.8	1,261.6	
CONVERSION AND LOSSES													
Electricity conversion losses											(17.4)	(17.4)	
Thermal electric generation							a/ c/				c/		
Charcoal production	(152.3)		30.4									(121.9)	
Trans. and dist. losses					(0.4)	(0.1)	(0.3)	c/		c/	(5.5)	(6.3)	
NET SUPPLY AVAILABLE	874.0	100.0	30.4	0.5	39.3	13.4	37.0	11.3	0.2	1.0	8.9	1,116.0	
EXPORTS					0.2	4.6						4.8	
NET DOMESTIC CONSUMPTION	874.0	100.0	30.4	0.5	39.1	8.8	37.0	11.3	0.2	1.0	8.9	1,111.2	100.0
As % of total	78.7	9.0	2.7	0.0	3.5	0.8	3.3	1.0	0.0	0.1	0.8	100.0	
CONSUMPTION BY SECTOR													
Industry	24.0			0.4		0.3	0.8	11.3		1.0	3.1	40.9	3.7
Transport					39.1	0.1	35.1			c/		74.3	6.7
Services	7.0					0.4	1.0		c/		3.8	12.2	1.1
Households	843.0	100.0	30.4	0.1		8.0	0.1		0.2		2.0	983.8	88.5

Note: LPG = Liquefied petroleum gas.

a/ Gatsata diesel station used 30 tons of diesel to produce 118 MWh (megaWatt/hour) in 1987.
b/ Account has been taken of illegal imports: 10.000 tons of diesel and 2.000 tons of gasoline.
c/ Quantity less than 50 TOE registered.

Source: Electricity balance from ELECTROGAZ (the Etablissement Public de Production, de Transport et de Distribution d'Electricité, d'Eau et de Gaz), petroleum imports from the Direction du Commerce Extérieur. Other figures are mission estimates.

1.16 The gross supply of primary energy in 1987 amounted to about 1.26 million TOE, made up as follows: fuelwood 1.03 million TOE (81%), agricultural by-products 100,000 TOE (8%), peat 500 TOE (less than 1/10 of 1%), petroleum products 103,000 TOE (8%), and electricity 32,000 TOE (3%). The major part of the difference between gross supply and final consumption in the energy balance was caused by conversion losses in electricity and in charcoal production, the balance being made up of transmission/distribution losses related to electricity and petroleum products plus sale of jet fuel to international airlines (categorized as exports).

1.17 Commercial energy consumption grew at an average annual rate of about 9% over the period 1980-87, considerably faster than GDP in real terms. Nonetheless, commercial energy consumption per capita and per unit of GNP remain lower than in other countries of similar size and income level (Table 1.3). This reflects, inter alia, the low level of development of the country as measured by various social and economic indicators, its dependence on agriculture, and the small size of the industrial sector. Out of the total quantity of commercial energy supplied in 1987 almost 80% was imported, almost all of it in the form of oil products. In monetary terms these imports weigh more heavily relative to merchandise exports than for most other comparable countries in Africa, despite Rwanda's low per capita consumption of commercial energy (see Table 1.3). Among other things, this confirms the burden on the country of the long and costly transportation for petroleum products.

Table 1.3: INTERNATIONAL COMPARISONS OF COMMERCIAL ENERGY CONSUMPTION, 1986

	Population (millions) a/	GNP/Capita (US$)			Energy consumption	
			(mn kgoe)	(kgoe/cap)	(kgoe/US$ GNP)	(Energy imports as % of merchandise exports)
RWANDA	6.6	285	106	16	0.06	31
Burundi	4.8	240	101	21	0.09	6
Benin	4.2	270	193	46	0.17	45
Niger	6.6	260	277	42	0.16	9
Guinea	6.3	320 b/	372	59	0.18	-
Somalia	5.5	280	451	82	0.29	8
Zambia	6.9	300	2,629	381	1.27	12
Senegal	6.8	420	789	116	0.28	25

a/ Mid-1986.
b/ 1985.

Note: Comparators are countries whose population and per capita GNPs are between 67% and 150% of Rwanda's. "kgoe" = Kilogram oil equivalent = 10,200 kcal.

Source: World Bank "World Development Report", 1988; mission estimates.

Investments in the Energy Sector

1.18 Historically, energy has had a small (but growing) share of total public investment. This is not surprising given the dominance of agriculture in the economy. For the Third Development Plan covering the 1982-86 period, energy represented 7% of total public investment. Investment in the energy sector grew at an average rate of 55% per year during that period, but growth rates for individual years fluctuated greatly. Energy, mainly electricity projects, represented 5.5% of total foreign-financed development expenditures for the 1982-86 period, reaching 15% of the total in 1987. With regard to domestically financed development expenditures, the energy sector captured about 4.5% of total expenditure for the Third Plan period and remained at about the same level in 1987. The Government's investment program for the 1989-91 period increases energy's share in total investment to 11%, again with projects in the power sub-sector dominating the energy sector program.

Energy Projections

1.19 No firm foundation exists for projecting Rwanda's future energy consumption. Some of the major factors related to energy supply and demand in the country and the issues raised in that connection are discussed in the following, however, and an indicative projection of future energy demand is presented. The issues are discussed in more detail later in the report in the context of the respective energy sources.

1.20 Woodfuels. Based on the available data, Rwanda is most probably under the present circumstances depleting its tree resources, with the impacts this has on increasing scarcity of woodfuels, soil erosion, and decreasing soil fertility. Four out of the country's ten prefectures are estimated to run a deficit between present demand and sustainable supply of woodfuels. Using present energy consumption patterns for households and official population projections, woodfuels consumption by households, the dominant consumer category, will be some 70% over present national demand just after the turn of the century. A few demand management programs with respect to woodfuels (production and end-use efficiency, and fuel substitution) are in progress or being planned. With reasonable assumptions as to their scope and effect, the savings on woodfuels are estimated to be only some 8% 15 years hence compared to the first forecast. Over the medium term, there are no alternative household fuels for cooking which in terms of availability and costs can on any significant scale replace woodfuels. The only exception may be kerosene, but that depends on a number of factors, including the pricing policies decided by the Government. The high population growth has been a major target for initiatives on the part of the Government and success in this area will be an important factor also in limiting the demand for woodfuels. Proposals for a new policy for woodfuels pricing and recommendations regarding the introduction of a tax on charcoal are other measures which, when introduced and vigorously enforced, should have positive effects on efficiency in production and end-use. On the whole, however, it would seem that the consumption of woodfuels over the medium term is bound to continue to rise at a rate fairly close to the rate of increase in population.

1.21 Petroleum products. Consumption of petroleum products is rising steadily and rapidly. Annual growth averaged 10% over the last ten years, despite generally low and occasionally falling GDP in the 1980s, but reflecting the coming on stream of some industrial enterprises. The structure of consumption is characterised by the predominance of automobile fuels, gasoline and diesel. The aggregate import cost of petroleum products currently equals around 40% of the country's total exports and their share may be expected to rise, since consumption of these products is growing faster than the total foreign exchange volume. Financing of petroleum product imports is therefore likely to become very difficult in the future and this will necessitate the adoption of a policy designed to balance the need to slow consumption growth for such reasons, with the legitimate energy requirements of different user groups. Depending on the impact of this policy, total consumption of petroleum products in the year 2000 is expected to be between double and triple of current consumption, implying an annual growth rate of 6-9%. Generally speaking, taxation and prices of petroleum products are quite high, at least in nominal terms. The level and structure of prices have, however, remained unchanged since 1981 and a review of taxation and prices in a broad context is now warranted. In order to limit the rise in consumption, the Government should draw up and implement programs for improving the efficiency of utilization of petroleum products and for replacing them by other forms of energy wherever this is economic. Energy audits to be carried out among large energy users, are expected to result in conservation measures. Among the various development directions explored up to now, the most promising appears to be extraction of Lake Kivu methane gas for alternative uses. However this is not an immediate option, as a number of issues (technical, institutional, economic, etc.) still need to be resolved.

1.22 Electric power. As previously indicated, electric power accounts for only a minor part in the total energy picture of Rwanda. Industry is at present the major consumer category for electricity. Over the medium term, no major changes are expected in Rwanda's general economic or export structure, nor are there any known plans for significant additions to present industrial capacity. Several studies have been done to analyze the issue of converting existing industrial fuel-fired boilers to electricity but they have concluded that the conversions are not economically or financially justified. Pending the demand forecast to be prepared as part of a Power Master Plan Study, preliminary electricity consumption projections have been made under different scenarios. The one adopted in this report is based on a growth rate of industrial electricity consumption of 3.0% per annum, slightly above the historical average, an increase in the number of residential and commercial users at an annual rate of 15%--reflecting the importance that the Government attaches to increasing the population's access to electricity--combined with a gradual decrease in unit consumption, and a growth in public consumption of 5% per annum. The resulting overall growth of consumption is close to 9% per year between 1987 and 2000, and residential/commercial consumers would become by far the most important consumer category. The demand forecast is particularly sensitive to increases in the number of new connections, which again is heavily influenced by the connection costs, at present very high. On the other hand, the electricity tariff for all consumer categories was until early 1991 relatively low and for certain consumer categories significantly below the long-run marginal cost (LRMC) upon which it should be based. Rwanda has in the past imported 10-20% of its electricity needs from Zaire. It would seem that Rwanda's electricity requirements can be satisfied until 1995, through a combination of generation from present domestic hydropower capacity and recourse to imports from the regional interconnected network. Thereafter, the options are developing potential regional or domestic hydropower sites, possibly in combination with gas-fired plants based on gas from Lake Kivu, depending on least cost and security of supply considerations.

1.23 Aggregate Projections. As shown in Table 1.4 consumption, based on the assumed growth rates, will around the turn of the century still be heavily dominated by biomass (83%). However, there will be greater shares of commercial fuels in overall energy consumption (petroleum products, 12%, electricity, 5%). In per capita terms, energy consumption increases to only a modest extent, from

191 kgoe to 214 kgoe (in terms of primary demand). The main reason for this relative stability in consumption pattern is that no substantial additions to industrial capacity are anticipated. Should methane gas from Lake Kivu be developed in the not too distant future, however, the projected relative shares of the energy sources could be expected to change from those shown in the Table.

Table 1.4: GROSS ENERGY DEMAND, 1987 and 2002
(In '000s of TOE)

	1987	Share %	2002 %	Share Rate	Growth %
Biomass	1,127	89	1,923	83	3.6
Petroleum products	103	8	284	12	7.0
Electricity	32	3	117	5	9.0
Total	1,262	100	2,324	100	4.2

Source: Mission estimates.

1.24 Even with a growth rate in petroleum products consumption of 10% p.a. (the growth rate of the last 10 years), biomass would still retain a share of close to 80% of the energy demand.

II. ENERGY INSTITUTIONS AND PLANNING

Institutions in the Energy Sector

2.1 Various ministries are involved in policy-making and supervision of energy sector activities. These include:

(a) the Ministry of Public Works, Energy, and Water (MINITRAPE) which, through its Energy Directorate (DGE), oversees the activities of the Etablissement Public de Production, de Transport et de Distribution d'Electricité, d'Eau et de Gaz (ELECTROGAZ), and formulates electricity pricing policies, takes the lead in planning of the power transmission and distribution networks and acts as executing agency for projects in most energy subsectors;

(b) the Ministère du Plan (MINIPLAN), which reviews the acceptability of investment projects in the context of macroeconomic priorities and manages the Study Fund which finances pre-investment and other strategic studies;

(c) the Ministère des Finances (MINIFIN), which controls the use of government budget funds for capital and recurrent expenditures and sets petroleum pricing policy;

(d) the Ministère de l'Agriculture, de l'Elevage et des Forêts (MINAGRI), which through its Forestry Department, is concerned with supply of woodfuel resources; and

(e) the Ministère du Commerce et de la Consommation (MINICOM), which sets the price structure for petroleum fuels.

2.2 Communication and coordination among the diverse ministries is generally good, owing in large part to the effective use of inter-ministerial committees (Commission Inter-ministériel de Coordination) as a forum for discussion and joint decision-making. While this process can be long, it serves to widely disseminate information among the sector's varied constituents and achieve a consensus which is well understood.

2.3 The Directorate of Energy in MINITRAPE has the lead role in formulating sector policy and development strategy, preparing and applying energy legislation, executing sector and investment studies, supervising projects, and maintaining sector statistics. This Directorate, created in 1984 by Presidential decree 176/06, has made a positive contribution to better coordination among Government ministries and agencies operating in the sector and to centralization of information. Major studies have been initiated, including the Power Master Plan, to provide information critical for the choice of domestic energy resource development and for rational investment planning. The Directorate has relied primarily on external experts to execute these studies, but should prepare a plan to develop its own capability in this area: economists and financial experts should be added to the staff, and key personnel in the project selection and planning process should also receive training to improve their analytical skills and understanding of generally accepted project analysis methodologies and energy planning issues. Of particular importance for the Directorate will be the development of adequate information and skills for the analysis of interfuel substitution possibilities.

2.4 The Directorate's knowledge of the energy sector is at present incomplete as it does not follow the behavior of the petroleum subsector. Data should be kept on the international market as well as domestic pricing, consumption, market locations, etc., in order to establish trends and to provide advice to fiscal authorities on international price movements and on supply and demand responses to domestic pricing changes. The Directorate needs to be more involved in strategic issues related to the petroleum sector, in particular in matters regarding supply security, petroleum stockpiling, and initiatives to increase end-use efficiency of petroleum products and interfuel substitution. Also, since much of the investment in domestic energy resources will be aimed at replacing imported petroleum products, a knowledge of markets, and the various price components (purchase price of imported products, transport, taxes) will be necessary to determine the competitiveness of different energy sources.

Institutional Organization within the Woodfuels Subsector

2.5 Although fuelwood is the most important source of energy, no one government institution has an in-depth understanding of both fuelwood supply and demand questions. The New and Renewable Energy Division of the Directorate of Energy manages a program for the development and dissemination of improved charcoal cookstoves and follows closely a MINAGRI program to introduce improved charcoaling techniques. Execution of the program and management of woodfuel supply data are however left to MINAGRI which sets forestry policy in general, but has no energy responsibility. The Directorate of Energy through its New and Renewable Energy Division should take a more active role in acquiring knowledge and the monitoring of woodfuel/charcoal supply, particularly in the Kigali supply areas, and undertake supply/demand analysis for this major energy source. The New and Renewable Energy Division should be given the responsibility for household energy planning and follow fuelwood and charcoal supply from the consumers' point view. This broader view would have the advantage of an integrated approach to reducing woodfuels demand by not only supporting actions to make consumption of these fuels themselves more efficient, but also by knowing the substitution possibilities of other energy forms and designing policies to encourage their efficient use. As an important part of the Government's strategy is to make modern forms of energy available to a larger number of household consumers, the Division would need to understand the very basic problems of the main imbalances in the supply/demand pattern for household fuels in general and to define the rules for public vs private development of improved household energy management technologies. This unit would also maintain information flows among the various executing and planning agencies.

Institutions in the Power Subsector

2.6 ELECTROGAZ is the wholly Government-owned national power company. ELECTROGAZ has the monopoly right to operate the national interconnected power network which is supplied primarily from four domestic hydroelectric plants. Information on the organization of institutions within the electricity sector and on ELECTROGAZ internal structure are given in Chapter V, which also contains specific recommendations regarding the restructuring of the company.

2.7 In addition to its ownership of ELECTROGAZ, the Rwandan Government is a one-third shareowner in the Société Nationale d'Electricité des Pays des Grands Lacs (SINELAC). This company was created in 1983 by a treaty ratified by the Governments of Burundi, Rwanda, and Zaire to build and operate the Ruzizi II power plant located on the border between Rwanda and Zaire. As a partner in SINELAC, Rwanda is entitled to one-third of the 26.6 MW of this plant. It is also envisaged that the three countries will share the costs of the plant's additional 13.3 MW unit which should be installed by 1995. Due to surplus installed capacity in Burundi and Zaire, Rwanda has the opportunity to purchase from SINELAC the energy not needed by the other two partners. This could be an interesting option for Rwanda if the economic cost of Ruzizi II's power is lower than that from the construction of new domestic plants. The least cost supply of new energy will be examined during the preparation of the Power Master Plan.

2.8 In recognition of the benefits of regional cooperation, Rwanda is also an active member in several organizations which promote regional energy development. The first of these is the energy affiliate of the Communauté Economique des Pays des Grands Lacs (CEPGL), known as the Organisation de la CEPGL pour l'Energie des Grands Lacs (EGL). Established initially as an independent organization in 1974, prior to the creation of the CEPGL, EGL's initial role was to plan regional electricity generation and transmission projects to the benefit of its three member countries: Burundi, Rwanda, and Zaire. Its role was subsequently broadened to that of a regional institution covering the entire energy sector. EGL's major task in its early years was the planning of the Ruzizi II hydroelectric power station. In recent years, it has undertaken a variety of planning studies and pilot testing programs of new energy technologies. In the future, EGL will undertake two activities aimed at ensuring new, low cost energy supply to the region and better coordination of network operation. Following completion of Rwanda's Power Master Plan, EGL will integrate its results with those of the completed Zaire and Burundi Master Plans and compare planned national generation investments with options for further development of Ruzizi River sites to derive a Regional Master Plan for expansion possibilities. In addition, EGL has initiated a study which will make recommendations for a better coordinated operation of the three national power networks which together form an interconnected regional network.

2.9 The second regional energy-related entity in which Rwanda is a member, together with Burundi, Tanzania, and Uganda, is the Organisation pour l'Aménagement et le Développement du Bassin de la Rivière Kagera (OBK) created by a multi-government treaty in 1977, to plan and execute projects in the agriculture, transport, industry, communications, and energy sectors aimed at an integrated development of the Kagera Basin region. Concerning power, a plant of between 60-100 MW to be situated 2 kilometers (km) downstream of the confluence of the Kagera and Ruvuvu Rivers has been studied through the feasibility phase. Discussions are continuing, but no decision has yet been made whether and when the proposed power development will be realized.

The Petroleum and Gas Subsectors

2.10 The petroleum sector is the most market-oriented of the energy sub-sectors, with private companies being the dominant agents for importation of products, as well as their transportation, distribution, and retail sales. This arrangement has proven so far to be a quite efficient one as evidenced by the ready availability of petroleum products all over the country at prices reflective of costs. However, some recommendations are made aiming at making sector institutions more effective, as discussed in para. 2.4 above, and emphasizing the need for the Energy Directorate of MINITRAPE to increase its involvement in strategic issues in the petroleum sector and to monitor behavior of both international and domestic market factors.

2.11 The Commission Technique Mixte Zairo-Rwandaise is the decision-making body for development of methane gas from Lake Kivu. The Commission, together with the CEPGL which serves as its secretariat, has undertaken various technical and economic studies of different gas extraction possibilities, although no choice has been made from among several onshore and/or offshore options. The pilot project to supply gas to the BRALIRWA brewery in Gisenyi has been managed by ELECTROGAZ. Future development has been conceived to be carried out, in accordance with a treaty signed by the two countries in May 1975, by a jointly-owned company, the Société Internationale d'Exploitation, de Transport et de Commercialisation du Gaz Méthane du Lac Kivu (SOCIGAZ). SOCIGAZ was originally viewed, as can be construed from its name, as being the sole operator responsible for all aspects of gas extraction and marketing. More recently however, there are indications of interest to consider a larger degree of private sector participation and to reduce the role of SOCIGAZ accordingly. Should supplemental studies on alternatives for optimal gas extraction and distribution provide economically viable technical solutions and identify an adequate market for raw and compressed gas, a strategy should be developed for searching out potential private sector partners. A promotion of Lake Kivu's gas deposit should be envisaged to test private sector interest and work on the legal structure of SOCIGAZ and on the institutional framework for private sector involvement should be finalized.

Sector Institutions and the Planning Process

2.12 Projects to be retained in Rwanda's public investment program should be selected based on their coherence both with national objectives and those sector objectives set forth in a strategy prepared by the responsible technical ministry. The economic viability of a project should be given sufficient weight among the criteria for project selection. While most projects in the proposed energy sector program, i.e., largely projects for power network development, have at least been subjected to pre-feasibility studies, a more rigorous approach is envisaged in the future. Beginning with the electricity sector, MINITRAPE and MINIPLAN have decided to prepare a long-term least-cost Power Master Plan comprised of projects which will meet tests of technical optimality as well as economic and financial viability. Rwandan planners will be trained in the various methodologies of project selection used in preparing the Plan so that it can be updated annually. The first Power Master Plan should be finished before the end of 1992. Once the techniques of planning and programming have been mastered for the power sector, MINITRAPE should begin global sector planning on the same basis in order to arrive at a long-term Energy Sector Master Plan. The development of a global master plan, sector strategy, and the policies to achieve them is quite naturally the mandate of a ministry responsible for the energy sector.

2.13 At present, MINITRAPE, rather than ELECTROGAZ, plans and programs electricity investments for production and transmission development, leaving planning of only the distribution network to ELECTROGAZ. Most of MINITRAPE's planners are former ELECTROGAZ staff whose departure has left a major void in ELECTROGAZ' planning capacity; ELECTROGAZ now has only a small planning unit comprised of electrical and electro-mechanical engineers plus technicians for supervision of works. The unit has no role in the planning and programming process as it is carried out by MINITRAPE which liaises instead with ELECTROGAZ' Technical Services Department for the execution of generation and transmission projects. For ELECTROGAZ to function as a normal power utility, it needs to participate actively in the planning process for the entire network and, ideally, take over this responsibility; high priority should be given to training planners for ELECTROGAZ. The ministry's role would then become that of a regulatory agency which ensures the overall appropriateness of the recommended investment plan with the sector strategy and which is responsible for preparation of a sector-wide plan which integrates all the subsectors within its domain.

Recommendations

2.14 The recommendations of the mission with regard to highest priority actions for improved performance of institutions in the energy sector are the following:

(a) comprehensive sector planning should be instituted in the Energy Directorate of MINITRAPE and its role and responsibilities vis-à-vis ELECTROGAZ and MINIPLAN should be defined;

(b) the planning capacity in both the Energy Directorate of MINITRAPE and ELECTROGAZ should be strengthened by developing the analytical skills and understanding of project analysis methodologies and energy planning issues;

(c) the Energy Directorate's areas of expertise should be expanded to cover the entire energy sector by adding to its responsibilities: (a) the monitoring of the petroleum sector and the formulation and follow-up of petroleum policy in cooperation with the Directorate of Foreign Trade and the Ministries of Finance and Planning; and (b) collection and analysis of supply and demand data for woodfuels/charcoal, monitoring of energy consumption from a household energy perspective, project supervision and donor coordination, in close cooperation with the Forestry Department within MINAGRI; within DGE it is proposed that the New and Renewable Energy Division be assigned these functions; and

(d) in addition to strengthening ELECTROGAZ' planning capacity as such, generation and transmission planning should be incorporated with distribution planning, ideally within a Planning Department in ELECTROGAZ.

III. BIOMASS & HOUSEHOLD ENERGY

Current Pattern and Level of Household Energy Consumption

3.1 In Rwanda, most of the household energy demand is for cooking. As in most African countries, pattern of usage is largely influenced by the user's location, with a predominance of charcoal consumption in urban areas and fuelwood in rural areas. In cooler regions of Rwanda, wood burnt for cooking also plays a significant role in home heating. Other household energy consumption forms include, to a limited extent: ironing, lighting, refrigeration, and use of various appliances (radios, tape recorders, etc.).

3.2 Several surveys have been conducted in the past, usually as part of larger undertakings, to assess household energy consumption, both in the urban and rural areas of Rwanda. These surveys resulted in various estimates of per capita consumption. The average figures vary over a wide range, especially for fuelwood consumption. After discussions with national specialists, a set of estimates was produced to determine the present level of household energy consumption. The following tables show the energy consumption in Rwanda, both in original units (kWh, tons) in primary energy (conversion efficiency of charcoal production and electricity generation included), as well as energy end-use.

Table 3.1: HOUSEHOLD ENERGY CONSUMPTION - 1987
END-USE

	Electricity	Kerosene	LPG	Agri by-products	Wood	Charcoal	Peat	Total
Unit	MWh	'000s tons						
Urban	23,773	8.1	0.2			40.0	0.5	
Rural	48	0.1		300	2,213			
TOTAL	23,821	8.2	0.2	300	2,213	40.0	0.5	
Unit	'000s GJ							
Urban	86 a/	339	11	0	0	1,200 b/	6	1,642
Rural	0	3	0	4,200	35,408	0	0	39,611
TOTAL	86	342	11	4,200	35,408	1,200	6	41,253
Percentage	0.2	0.8	0.0	10.2	85.8	2.9	0.0	100.0

a/ Power generation efficiency = 34%.
b/ Charcoal production efficiency = 10% (weight basis).

Source: Mission estimates.

Table 3.2: PRIMARY ENERGY USE, 1987

	Electricity	Kerosene	LPG		Agri. by-products	Wood	Wood for Charcoal making	Peat	Total
Unit	MWh	------------------------------			'000s GJ	------------------------------			
Urban	67,923	245	339	11	0	0	6,400	6.0	7,000
Rural	137	0.5	3	0	4,200	35,408	0	0.0	39,612
TOTAL:									
(in '000 GJ)	68,060	245	342	11	4,200	35,408	6,400	6.0	46,612
(in kTOE)		7.1	8.1	0.25	100	843	152	0.1	1,111
Percentage	0.6	0.7	0.0	9.0	75.9	13.7	0.0	100.0	

Source: Mission estimates.

3.3 In primary energy terms, the overall household energy consumption is around 1.11 million tons of oil equivalent per year (TOE/year) (see Table 3.1). In this total, the share of "modern" fuels, like kerosene and liquefied petroleum gas (LPG), is minimal and, together with electricity, account for less than 2% of household energy consumption. Conventional electric power is considered to be consumed only in urban areas. Power consumption in rural areas is in practice based on small batteries.

3.4 Fuelwood (76% of primary energy consumption), agricultural residues (9%), and charcoal (14%, but only 3% measured in end-use), are the major sources of household fuels utilized (see Table 3.2). The quantities used are in the range of those usually recorded in other parts of Africa (in fact, one major survey in Rwanda had average results similar to those in Sahelian countries, the other one had average results similar to those in other African highlands). Although charcoal consumption consists of only a small percentage of national energy end-use, its detrimental effects to the environment are large because charcoal production efficiency is low and because charcoal production is a commercialized process. Some of the estimates given in Table 3.1 differ notably from earlier ones. The newer estimates are based on the results of recent surveys which show that the fuelwood consumption per capita is lower than previously estimated and the proportion of wood used for charcoal is larger (see Annex 1.1).

Pattern of Biomass Fuels Demand

3.5 Fuelwood is not only used by households, but also by industry and miscellaneous services. In most cases, basic information on these consumption figures is just as barely reliable as that on household use, with the exception of the tea industry for which l'Energie des Grands Lacs (EGL) has produced reasonably good estimates for 11 factories. Results from compilation of available statistics are given in Annex 1.2. From the table it is apparent that most of the demand (96.9%) comes from households, the rest being shared between industry (2.4%) and miscellaneous services (0.7%).

3.6 Although the household sector's share of the overall fuelwood consumption is by far the largest, reducing this consumption is not easy: less than 10% of the households use charcoal while the bulk uses firewood or a mix of firewood and agricultural residues as their main household fuel.

Conservation of woodfuels in the rural areas is much more difficult than in urban areas because the woodfuel sector is much less commercialized than the charcoal sector. On the other hand, woodfuel consumption in the institutional and artisanal sector, and in cottage industries is highly commercialized (although representing only a small share of the total energy consumption) and therefore, prospects for conservation exist here. Main targets for woodfuel conservation efforts are schools, small hotels, restaurants, prisons, hospitals, military camps, etc.

Current Household Fuel Supply

3.7 In broad terms, rural dwellers get their supply from plantations and forests, and material gathered from trees and agricultural fields in their neighborhood. Though a lot more information is required to fully describe the supply pattern, the situation is relatively simple and easy to characterize in these rural areas: wood and agricultural residues (dried banana leaves, maize stalks, etc.) are collected--not purchased--by family members, stored for a few days, and burnt in open fires.

3.8 Urban dwellers have a more complex and diversified supply pattern. They use a combination of traditional (woodfuels) and modern fuels. Even when they use traditional fuels, they purchase it from sellers. In order to simplify the present analysis, and for lack of any precise description, it has been assumed that urban centers consume charcoal and almost no fuelwood, and that rural areas consume mainly fuelwood and almost no charcoal. With the significant uncertainties related to data on traditional fuels in general, a national survey of fuels used in rural areas should be conducted, to enable the authorities to obtain a better basis for planning rural energy supply and conservation measures.

3.9 Over the years, the best studied fuel has been charcoal, as it is: (i) a marketed product; (ii) a major source of energy wastage during conversion; and (iii) part of a process that offers potential for many improvements, both at the production and utilization levels. A study was undertaken in late 1987 as part of the "Improved Technique for Charcoal Production and Improved Charcoal Stoves" project under the joint UNDP/World Bank ESMAP program, in cooperation with the Ministère des Travaux Publics, de l'Energie et de l'Eau (MINITRAPE) and the Ministère de l'Agriculture, de l'Elevage et des Forêts (MINAGRI). This study has been used extensively for the present Chapter and is later referred to as the "Secteur Charbonnier" study.

3.10 Prior to 1985, the main charcoal production area used to be the eastern savannah of Bugesera and Kibungo. This resulted in vast numbers of trees felled from natural stands and loss of natural cover. In early 1987, the Government reacted to this negative trend and encouraged the shift of charcoal production areas to the West and South-West (Gikongoro) by forbidding the use of the savannah areas. Like in other sectors of the economy, the economic agents were very fast in responding to the Government's decision and, consequently, the shift took place quickly and without major problems. The "Secteur Charbonnier" study shows that as much as 55% of the charcoal purchased by Kigali retailers now comes from the Gikongoro area. Kibuye (west) comes second for this study with 18% of the total. Annex 3.3 displays the distribution of charcoal supply by prefecture.

Forecast Household Energy Consumption to Year 2002

3.11 The household energy consumption has been projected using present consumption patterns and the trends in population growth as the main parameters. Several population projections are being currently made for Rwanda. The projections utilized for this estimate are the central assumption of the Office National de la Population (ONAPO) for total population and the World Bank's for urban population (see Annex 1.4).

3.12 Two scenarios have been prepared for the projections to year 2002: one being the continuation of present trends (Scenario I), the second one including demand management policies (Scenario II: increased end-use efficiency, increased carbonization efficiency, fuel substitution in particular). Demand has been estimated both in physical terms and in TOE. The assumptions and the resulting household energy demands are presented in Annex 1.5 for Scenario I.

3.13 Only Scenario I will be commented upon here; Scenario II will be commented on later after having considered certain conservation and substitution measures. As can be seen in Annex 1.5, household energy demand in year 2002 is estimated at 1.9 million TOE, an increase of some 70% over the present national demand. With respect to woodfuels, Kigali prefecture alone will represent some 29% of the national total, increasing by some 140% over present prefecture consumption. This is the result of high population growth combined with an increasing proportion of charcoal into the woodfuel mix. The implication is that the capital city will be playing an increasing role in determining the basic parameters (prices, quantities) of the marketed charcoal in Rwanda. As in most other African countries, this furthermore means that "imports" of charcoal into the city will be a growing part of all goods movements and of road traffic in general, with all associated side-effects, e.g., more use of energy (i.e., petroleum fuels) for transporting energy. These developments, together with the effects on natural resources, make it necessary to place considerable emphasis on the study of charcoal in a broad context in Rwanda.

3.14 Under Scenario I, fuels other than woodfuels and agricultural residues play a negligible role in meeting the overall household energy demand (2.1% in year 2002). This would also apply in a case where household electricity consumption increased at the higher rate assumed in the forecast in Chapter V. Modern fuels would even then account for only 3-4% of household energy consumption. Similarly, uses of traditional fuels outside households are only a marginal fraction of woodfuels and biomass used for household purposes.

Estimate of Sustainable Woodfuels Supply from Existing Sources

3.15 The country has a total of 436,200 ha of natural forest located in and around three National Parks. In addition, there are 35,200 ha of forestry domaines, 44,600 ha of village forests, and

149,000 ha of private forests and "arborisation"; in total 665,000 ha. 1/ This is the equivalent of 25% of the country's total land area. As recently as five years ago, arborisation as part of a deliberate attempt to improve the fuelwood supply situation was virtually non-existent. Due to the initiatives by the Direction Générale des Forêts (DGF), which were followed up by the farmers, arborisation has become one of the prime instruments in the efforts to increase wood production. Now, most of the firewood comes from the arborisation and the private plantations, arborisation alone estimated to contribute more than 50%. Rwanda has a high density of nurseries, approximately one for every 5,000 people.

3.16 An estimate has been made of the supply that could be obtained from existing and future wood sources on a sustainable basis, i.e., without depletion of the stock. The sustainable supply includes arborisation, plantations, natural forest, and savannah trees. A regionalized woodfuel supply estimate for 1987 has been prepared and is shown in Annex 1.6, which also contains the assumptions.

3.17 As can be seen from the Annex, woodfuels are produced in all prefectures with quantities varying from a low 171,000 tons/year, in Kibuye, to a high 317,000 tons/year, in Kigali. Arborisation alone represents 56% of the total sustainable supply nationally. In essence, this means that Rwandan households get their main supply from the fields of farmers. The second major source of woodfuels is the plantations which contribute globally to a third of the sustainable supply. This proportion reaches a high of nearly 45% in Ruhengeri, where large plantation efforts have been made during the past 10 years, and is as low as 11% in Kibungo. In absolute terms, the major contribution from plantations is for Gitarama prefecture. A sizeable part of the sustainable supply (9%) comes from natural forests, a source from which it is illegal to collect wood. In practice, many rural dwellers get their supply from natural forests, though no statistics are available on this subject for obvious reasons.

Woodfuels Balance

3.18 The balance between demand and sustainable supply has been computed for the country as a whole and for each prefecture based on the assumptions above (see Annex 1.6). There is at present an estimated national deficit of 500,000 tons of woodfuels compared to sustainable supply, representing 16% of the total demand. Out of the 10 prefectures, 4 recorded a deficit, the largest in absolute terms being Kigali with 239,000 tons and the largest in relative terms being Ruhengeri with almost 50% of the demand. This shows that under present circumstances Rwanda is most probably depleting its tree resources, partly from natural forest though the corresponding quantity is impossible to assess at present. This indicates that the situation is already imbalanced, and that corrective action is required.

3.19 The situation threatens to deteriorate in the future. Annex 1.7 provides the assumptions for increased woodfuels supply in the near future and the resulting supply/demand balances for year 2002. Even at the ambitious pace, according to the "Plan Forestier National" produced by the Rwandan government, it appears that the gap between demand and sustainable supply will continue widening. In

1/ *All data: 1985. "Gestion des Ressources Forestières en Vue de Satisfaire la Demande en Bois de Feu et Charbon de Bois"; MUTUNGIREHE Isaie, Directeur Général des Forêts, Ministère de l'Agriculture, de l'Elevage et des Forêts. Arborisation represents trees that are scattered in a farmer's field.*

year 2002 only 3 out of the 9 prefectures would experience a deficit, but the total deficit is larger than in 1987 (1 million tons vs 500,000 tons). This would be a very serious situation with both financial/economic and environmental consequences. A rough calculation shows that the plantation area would have to be increased by 70,000 ha over the period up to year 2002 (with a productivity of 15 t/ha/year) to make it possible to supply woodfuels on a sustainable basis, an objective clearly out of reach of the Government under present circumstances. On the technical side, several measures will have to be taken and, notably, there will be a need to look closely at the possibility of transferring large amounts of woodfuel over some distance in addition to the required conservation measures. Given the present limitations of Government services in charge of forest development and conservation, the programs as they have been included are the maximum that can be reasonably achieved, so the actual results may even be inferior to these predictions, making corrective actions very urgent.

Wood and Woodfuels Pricing Policy and the Effectiveness of Cost Recovery

3.20 Wood pricing and charcoal taxation in Rwanda was examined as part of the "Secteur Charbonnier" study. At present, woodfuel prices are free-market prices, the only Government intervention being that of setting stumpage fees at RF 400/stère (US$5.30/stère) for wood originating from public forests. The study analyses the operation of the present system and makes proposals for mechanisms that would improve the conservation of forest resources. One of the conclusions is that the official price of RF 400/stère for standing trees is hardly ever used, most of the transactions taking place below RF 100/stère, with a few exceptions between RF 100 and RF 200/stère. These prices are below actual costs of plantations (see below). This is due to the low selling prices of woodfuels on the urban markets, as well as to the lack of (higher value) alternatives to selling standing trees for woodfuels. The low market price reflects the combination of generally low purchasing power of consumers relying on fuelwood for cooking, limited markets for commercial fuelwood, and supply from sources where the total cost of the wood is not fully perceived by the supplier. As an example of the latter, it may be mentioned that fuelwood even from communal plantations is sold at the low prices quoted above since communes sometimes fail to see the direct connection between the costs of establishing and running a plantation and the actual price charged for the wood. The stumpage fee is in such cases only partly enforced and for supplies from private sources the fee does not apply at all. In the present situation, therefore, the Government, communes, and small farmers may be said to be subsidizing the urban consumers by selling their trees well below the cost of sustainable supply. Annex 1.8 shows the costs of plantations with different types of ownerships.

3.21 It is presently of major concern to the Government that the prices of all forest products, and not only of woodfuels, should reflect more closely the real cost and that they lead to commercial operations. DGF submitted, in January 1988, to the Government a proposal for a new wood pricing policy. The policy aims to lay the basis for "fair" prices providing reasonable incentives to both producer and user to maintain a sustainable supply of wood products. It is meant to apply to all categories of producers and users. The prices comprise three categories of wood: fuelwood, building poles, and timber. Prices for fuelwood, expressed in RF/stère and translated into RF/kg, are summarized in Annex 1.9. The World Bank, in the course of the preparation of the Second Integrated Forestry Project proposed: (i) introducing a price revision formula for regularly adapting the woodfuel prices;

(ii) reversing the price relationship between pine and eucalyptus timber; and (iii) increasing the allowance for transportation costs of fuelwood. The Government may incorporate these comments in the final version of the pricing proposal, although no official reply has been made so far. It should be pointed out, however, that the proposed prices do not cover production costs for all types of plantations, notably state plantations, as shown in Annex 1.8.

3.22 It is recommended, here, that the new price policy, differentiating the price of fuelwood according to location of plantations and tree category, should incorporate the recommendations made under the Second Integrated Forestry Project. However, introducing some rationality in the wood market will not be easy, as this is a sector where producers and users are very scattered, often illiterate and where informal activities play a major role, particularly for woodfuels. The publicity campaign and taxation proposals made under the Improved Stoves and Kilns Project should form an integral part of the action plan to address these issues. The Government should, in any event, be very specific with respect to the field of application and the measures of enforcement. It is an issue of concern that the staff limitations in DGF will make it difficult to implement the new price policy. A greater emphasis is required to increase the staff and improve their qualifications before any large scale forest development and conservation policy is implemented.

3.23 The price of charcoal is a free market price and there is at present no Government intervention in the price build-up, except for stumpage fees. This may change in the future with the proposed introduction of a charcoal tax. At present, the main determinants of charcoal price are the distances from the production sites to the main consuming center of Kigali and the mode of transportation. The technology utilized throughout the country is the traditional kilns-type with practically no material investment by the charcoaler. An analysis of the economics of the charcoal industry has been made, which results in the cost breakdown shown in Annex 1.10. As can be seen, the price of charcoal in Kigali being what it is at present, the value of the charcoaler's labor is very sensitive to standing-wood prices. At the present official (but rarely applied) price of RF 400/stère, there would hardly be any incentive for the charcoaler to remain in business. Prices around RF 100/stère allow a monthly "salary" that is closer to normal expectations for a rural laborer.

3.24 The Government has announced its decision to introduce a tax on charcoal marketing. After all, charcoal is a costly fuel and should be valued accordingly. This tax system has been the subject of the study which recommends that this new tax should be levied by the communes for charcoal being transported in their territory. The communes have a rather strong local authority and supervise/maintain a large part of the country's forestry resources. A dual tax system should be implemented so as to encourage the use of improved carbonization techniques as well as to augment the revenues of the communes. Charcoalers adhering to traditional carbonization methods would pay a high tax of RF 60/bag out of which RF 12.50 would go to the communes and RF 47.50 to the Government. Charcoalers agreeing to adopt improved practices would only be charged RF 30/bag, out of which RF 25 would go to the "commune" and RF 5 to the Government. Transporters who have to pay the tax, are told where they can find villages where the improved techniques are practiced. The existing system of charcoal transport permits ("carnets") will be adapted to the new system which means that the village will have to stamp the permit to indicate the origin of the charcoal. Occasional checking by forestry officials and police will allow a certain degree of control and bookkeeping measures.

3.25 The argument is that with the present low resource cost and no tax on charcoal, there is indeed little incentive to use improved carbonization methods. Using the official wood price in combination with improved carbonization techniques would produce larger incomes in return for increased financial investments. The basis for this estimate is described in Annex 1.11. The introduction of the proposed tax, in combination with an educational campaign and, consequently, the adoption of improved carbonization techniques would help achieve three sets of objectives: increase charcoalers' income, conserve the resource, and increase public revenue both on the communal level and the national level.

3.26 The practical feasibility of implementing this new charcoal tax is still an open question. As seen before, the official price of standing wood is, under the present circumstances, hardly ever used. However, the approach proposed in the "Secteur Charbonnier" study is valid. It is proposed to continue with the awareness campaign for promoting improved charcoal techniques and creating awareness on the actual value of wood prior to implementing any taxation policy. With that strategy it may be possible to establish the proposed taxation system, although practical measures, like making the distinction between a bag of charcoal produced with improved and with traditional carbonization techniques without too much involvement of police or other controllers, need to be looked further into. In conclusion, the strategy recommended by the "Secteur Charbonnier" study is considered a rational one in the present context and its implementation should be encouraged.

Measures to Strengthen Wood Supply Programs

3.27 A series of projects aim at narrowing the gap between demand and sustainable supply of woodfuels. They are listed in Annex 1.12, along with the donors involved, and include projects to increase fuelwood supply and conserve fuelwood, and measures to strengthen the DGF. It clearly appears that Rwanda is attracting considerable external aid in the management of natural resources. The present level is probably close to the absorption capacity of the Government. Except for the management of natural forests on the Zaire-Nile crest where a certain degree of donor coordination has been achieved, most externally funded projects have lacked planning and coordination. The "Plan Forestier National" by the DGE should form the basis for improved coordination in the future of donor assistance. This national plan consists of an ambitious set of efforts on the part of farmers, communes, and the Government in a country where land shortage is one of the major development constraints. Its global objectives, summarized by the DGF in a recent policy paper are as follows:

(a) the establishment and maintenance of a country-wide ecologically balanced forest resource;

(b) the increase in forest production; and

(c) a better utilization and upgrading of forest production.

3.28 Although still in its initial phase, the plan has attracted considerable donor attention. Two of the projects which form a basis of the plan and which focus particularly on strengthening wood supply call for some comments:

(a) the recent World Bank Forestry II Project is also involved in range management/livestock activities. In the forestry field, the Project is mainly concerned with natural forest protection and management on the Zaire-Nile crest, as are other projects (the French Caisse Centrale de Coopération Economique [CCCE], Switzerland, EEC);

(b) the Swiss technical assistance has played a major role in helping the DGF establish the basis for a sound forestry policy, as well as in training a large number of forestry specialists at various s[illegible]ls.

3.29 It is clearly impossible for the Government to implement its ambitious program without: (i) external financial support; (ii) the development of human resources in the forestry sector; and (iii) the development of major outlets for non-fuelwood products. The external financial support is more than likely to be continued in a country with past records of heavy external involvement in development financing. At present, 75% of the US$6 million/year of forestry sector expenses are covered by external aid, 55-60% of this being loans. The development of human resources is an absolute must in a country where only 25 forest engineers and 50 forest technicians are presently active in Government service. Finally, the development of new and efficient uses of wood products is one of the major Government objectives, and a very demanding one. There are plans to promote the various wood uses in the future. At this stage, it is too early to try to assess the chances of seeing this vast program succeed but clearly it must do so to a major extent, as the development of plantations will not be sustained by energy outlets alone.

3.30 The impacts of reduced plantation program achievements have been looked into in Annex 1.7 by simulating arbitrary shortcomings in the Plan achievements. These shortcomings have been assumed to be mainly in the plantation program, which is the most sensitive part, being: (i) the largest single wood producer; and, (ii) a joint venture between the Government, the communes, and the population, thus making it technically vulnerable. The results of the analysis show that the overall woodfuels deficit is a direct function of the extent to which the Plan achieves its target: when the 1988-2000 plantation program drops by 20%, the overall woodfuels deficit increases by 120,000 tons/year, or 11% per year. The Government and donors should be conscious of that sensitivity and try to ensure the continuity of their efforts to promote the Plan Forestier National.

Current and Planned Woodfuel Conservation Measures

3.31 Woodfuels conservation is the objective of three presently independent sets of efforts which are coordinated by the Ministère des Travaux Publics, de l'Energie et de l'Eau (MINITRAPE):

(a) global fuelwood conservation, in the form of the "Economie de Bois de Feu" (EBF) project;

(b) charcoal end-use reduction, mainly in the form of more efficient charcoal stoves through dissemination by the private sector;

(c) wood conservation through dissemination of more efficient carbonization techniques, which is jointly coordinated by MINAGRI and MINITRAPE.

3.32 The EBF project receives the assistance of a Dutch volunteers association. Its objective of conserving fuelwood is met through an extension approach, the technical part of which includes improved wood stoves dissemination. The extension program is quite comprehensive and primarily attempts at sensitizing women, in particular, to cooking techniques that require less fuelwood. Techniques tested so far include drying wood before burning it (though this was, after the field tests, identified as a currently used traditional practice), soaking the beans, and eventually building an improved wood stove. Several models of these are currently being tested in the training sessions. So far, it is a small project with little practical impact in the short run; but in the future it should design the methodology and set the standards to be used by extension services as part of their usual duties. An evaluation of the project will be required.

3.33 Two organizations provide technical and financial assistance on improved charcoal stoves. CARE INTERNATIONAL assisted an entrepreneur in starting production and marketing of the CANAMAKE stove, which is derived from the KENYA JIKO stove model. CARE INTERNATIONAL has completed its involvement and the entrepreneur now works on his own. He sells an average of 100-150 stoves per month of the most popular model at RF 500 and another 100 stoves of the other models (RF 600-1,500). Presently, he is also selling the RONDEREZA stove at the same outlets.

3.34 The RONDEREZA stove is developed by the World Bank and the United Nations Development Program (UNDP) which, in parallel have embarked upon a more systematic program to test and gradually disseminate socially acceptable models. The laboratory experiments have produced encouraging results for the improved stoves in terms of power charcoal consumption and savings that, over a short period of time, compensate for the higher initial stove cost (see Annex 1.13). During the following phase of the project, actual efficiency of the improved stores has been tested in conditions as close as possible to real life and average charcoal savings of 34% were obtained. The reception of the stoves among the families chosen to test them has been very positive and a publicity/marketing campaign has been launched as part of a large scale dissemination scheme. Preliminary results at the end of 1990 show that the stove is rapidly being adopted by stove producers and households, as indicated by a total of approximately 20,000 stoves sold during 1988-1990.

3.35 Improved carbonization techniques have been investigated by a Rwandan team with assistance from foreign consultants. As part of the project, charcoalers are trained on-site in the use of improved charcoaling methods, which are described in Annex 1.13. The performance tests of the improved kilns show improvements in efficiency of, on average, 60%.

3.36 MINITRAPE should start coordinating the various projects on woodfuel conservation. In addition, new efforts should be directed towards woodfuel savings in the institutional, artisanal, and cottage industry sector. Preliminary contacts should be taken with organizations that can play an active part in the future development of both charcoal and wood stoves. This is particularly the case with the Banque Populaire du Rwanda which has a very decentralized and active network of local banks capable of handling small loans, well-suited to the needs of artisans in charge of manufacturing the new stoves.

3.37 Besides the implementation of forestry projects and woodfuel conservation measures, it is clear that the basic problem of future woodfuels supply is linked to population growth in Rwanda. Projects dealing with purely technical aspects of trying to follow a growing demand for woodfuels basically proportional to population growth may easily miss their target. Population policies need to be considered in parallel, as forestry projects and conservation measures alone cannot be expected to have sufficient impact in the long run.

Woodfuel Substitution Options

3.38 Petroleum products that can be used to substitute woodfuels for cooking operations are mainly kerosene and LPG. These fuels are used to a very limited extent, and only in urban areas. However, if severe shortages of woodfuels and/or attractive price differentials were to be observed, these petroleum fuels could replace part of the woodfuels. Economic and financial analysis of potential substitution possibilities are presented in Annex 1.14. The results show that charcoal at present prices is a much cheaper alternative than petroleum fuels, and that there will hardly be any competition between them unless a dramatic price increase for charcoal, or further reduction in petroleum prices, should take place. As presently viewed, it is not expected that the proposed tax system will increase the price to charcoal consumers to any major extent. The increase in transportation distance, on the other hand, may turn out to have a larger impact on charcoal prices in the future. However it is not expected that the present 65% gap between the prices per megajoule (MJ) of kerosene and charcoal will be notably reduced in the years ahead. The main savings on woodfuels consumption are expected to come from a combination of demand and process management with respect to woodfuels as such and possibly from substitution from other biomass fuels (e.g., papyrus briquettes) in the longer term, if these prove to be viable alternatives in Rwanda.

3.39 The Government and donors have launched programs to introduce new fuels that could substitute part of the woodfuels presently used. The programs focus mainly on papyrus briquettes and peat. Experience on papyrus briquettes have a long history in Rwanda, and more details on present (pilot) operations and the potential of briquettes are given in Annex 1.15. In summary, papyrus briquettes could prove to be an alternative if certain issues are resolved. These include production cost--and thereby their competitiveness--which is seen as dependent upon the establishment of efficient production lines. To verify the competitiveness, economic analyses will be necessary and should be made before any decisions are taken to make further investments. Acceptability tests should be conducted and possible utilization problems reported.

3.40 Peat is being investigated as a possible substitute for other sources of energy both for the industrial and the household sectors, partly because of its abundance in Rwanda (estimates vary between 5 and 50 million tons of reserves). The Government has taken the initiative of launching a peat Master

Plan study. The mission has, therefore, concentrated on the experiments designed to supply peat to households as a cooking fuel, mainly for the Kigali area. The results of the limited investigations conducted during the field mission are that, at present, peat does not seem to be a viable competitor for charcoal for Kigali households. The main reasons for that are explained in Annex 1.16 and summarized below:

(a) peat exploitation is limited to very specific locations, mainly remote from large urban centers of consumption, and the cost of transportation makes it an expensive fuel;

(b) the practicality of peat as a household cooking fuel remains to be proven; and

(c) experience from other countries (e.g., Ireland) suggests that the environmental damage from large-scale exploitation of peat can be substantial.

This does not preclude conclusions that could be drawn relative to the exploitation and use of peat as an industrial fuel, which has been proposed for a feasibility study for the 50,000 tons/year cement plant of MASHYUZA. However, it has been suspended, pending the availability of a Peat Utilization Master Plan. In this study, means to save on the 35,000 liters of fuel oil used daily would be investigated. 2/ At present, the fuel cost for the plant is more than 60% of the cement cost and requires foreign currency for import. Most of the drawbacks identified for peat as a household fuel do not apply to industrial utilization. Consequently, industrial uses of peat merit investigation, although the potential use of gas as fuel for the cement plant would be an important element in the considerations leading to a development of Lake Kivu methane gas, as discussed in Chapter VI.

3.41 A tentative comparison between papyrus briquettes, peat, and other fuels for household use is presented in Annex 3.14. With the limited data available, it was not possible at this stage to make a distinction between financial and economic costs of all of these fuels. However, the indication is that, under present conditions and provided it is established that it can be used efficiently, papyrus briquettes could compete economically with charcoal. Peat appears too expensive at this stage to qualify as a valid competitor for charcoal. These conclusions are only tentative, however, and further investigations are required.

Alternative Household Energy Consumption Forecast

3.42 In Annex 1.17 a household energy conservation scenario (Scenario II) has been prepared which has the same point of departure as Scenario I (see para. 3.12) but includes the impact of certain woodfuel conservation measures. Using assumptions which are listed in the Annex, the potential for woodfuel energy conservation has been investigated by taking into consideration a combination of:

(a) final demand management (improved wood and charcoal stoves);

2/ *At the present annual rate of consumption of fuel oil at the cement plant, some 20,000 tons of peat would be needed.*

(b) process efficiency increase (carbonization); and

(c) increased use of papyrus briquettes.

With the reasonable assumptions used, the general savings on woodfuels by year 2002 is some 8%, and the alternative growth curve for woodfuel consumption lies only slightly below that of Scenario I (para. 3.14) as shown on the figure of Annex 1.18. The impacts are much less than required, in particular to achieve any substantial saving in woodfuels necessary to reduce the present deforestation. Here again, the role and importance of effective population policies is emphasized.

Institutional Aspects

3.43 The institutional situation regarding woodfuels is far from ideal. MINITRAPE considers that actions and data collection in this field are more under the control of DGF/MINAGRI whereas the latter has no explicit energy responsibility. To avoid overlaps and, conversely, gaps in the management of woodfuels resources at all stages, household energy planning should be the responsibility of one unit within MINITRAPE. Its main purpose would be to monitor the situation in the household energy field, as well as to make policy proposals and initiate/supervise projects in this field. It would have the following responsibilities:

(a) the monitoring and planning of resources and the supply/demand of woodfuels, particularly in the Kigali supply areas by means of identifying of a Master Plan for charcoal supply of Kigali; 3/

(b) the monitoring of projects dealing, in one way or another, with household energy, as well as monitoring of technical, economic, and financial data on available solutions for reducing or substituting woodfuels demand;

(c) the identification of programs to reduce the main imbalances in the supply/demand pattern for household fuels and to promote desirable interfuel substitution;

(d) the design and implementation of clear rules between the private and public sectors as well as NGOs in order to clarify areas of responsibility with the objective of improving management and promoting development of household energy technologies; and

(e) maintaining information flows with executing agencies and the Ministère du Plan (MINIPLAN) in order to produce periodical reports to be used in preparing the National Plan.

Household energy planning units have been or are being established in several developing countries, usually as part of broader efforts to implement energy policies. In all of these cases, household

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3/ *Particularly data on resource availability and fuel supply should be collected by MINAGRI.*

energy planning units have meant better coordination and improvement of information systems and proved to be very valuable for energy planning.

3.44 The location of a household energy unit (its rank within a ministry and to which ministry it should be assigned), as well as the need for technical assistance, at least in the initial stages, should be given consideration by the Government. However, there is little doubt that MINITRAPE offers several comparative advantages for hosting this unit, with its overall responsibility for energy management in the country. To avoid creating a new department, it is proposed that the present New and Renewable Energy Division within DGE should have its scope expanded to cover the said functions and be strengthened accordingly.

Recommendations

3.45 The following summarizes the mission's conclusions and recommendations:

(a) the ongoing household energy projects on improved charcoal stoves and charcoal production techniques are sound and should be continued. For the stoves project this would mean, inter alia, commence testing of efficiency under real life conditions and proceed with the important step of commercialization; for the improved carbonization techniques, training of more charcoalers is needed to spread the benefits of the observed efficiency improvements;

(b) the proposed new price policy for woodfuels, differentiating the price according to location of plantations and tree category, should be implemented, incorporating the previously proposed World Bank modifications. The recommendations of the "Secteur Charbonnier" study regarding a new dual charcoal taxation should be adopted to encourage the use of improved carbonization techniques and to augment the revenues of the communes, with the objective of saving wood resources. The proposed taxation system should be tried on a pilot basis before being extended to the nation as a whole in order to identify its feasibility in actual conditions;

(c) with the significant uncertainties related to data on traditional fuels in general, a national survey of the supply and demand of these fuels should be conducted, to enable the authorities to obtain a firmer basis for planning energy supply and conservation measures;

(d) the New and Renewable Energy Division within DGE should have its scope expanded and be given the responsibility for monitoring/supervising projects in the household energy area and coordinating donor activities; this would imply training and strengthening of staff in data collection methods, economic analysis, and energy planning issues;

(e) assistance to strengthen the DGF staff, initiated by the Swiss Cooperation, should be continued and expanded by increasing the number of qualified forestry staff in order that the DGF be able to respond to the major challenges in the traditional energy sub-sector (such as the implementation of large scale forest development and conservation policy). One of the specific tasks of DGF would be to improve coordination efforts between projects and programs designed to increase plantation rates and utilization of timber with those dealing with woodfuels, as both have a strong potential synergy;

(f) a concise socio-economic evaluation should be conducted to identify the viability of papyrus briquettes as a household fuel, a subject largely overlooked so far. This should best be done in conjunction with the present production research;

(g) the link between biomass energy development and environmental protection and management should be given greater emphasis by the Government and donors. Of particular relevance to household energy are the following aspects: impact of peat exploitation on the environment, impact of papyrus harvesting, regional aspects of forest/plantation exploitation for woodfuels production. Reference is made to the recommendations in Chapter VIII on environmental aspects; and

(h) the link between population growth, household energy demand, and pressure on natural resources should be kept in mind in all policy making decisions, and efforts to "bend the population growth curve" should be made whenever possible, as this is the main element in easing the woodfuels situation in the long run.

IV. PETROLEUM PRODUCTS

Overview

4.1 Petroleum products account for about 80% of commercial energy consumed in Rwanda. They are entirely imported, constituting approximately 16-17% of the country's total import bill. Supply of oil products to Rwanda is affected by two specific difficulties: high prices and unreliability, both linked to the country's geographic location and the condition of the transportation infrastructure in that part of Africa. Political unrest in Uganda, through which the main supply route for oil products passes, has from time to time caused supply cuts lasting weeks or even months. While there have been no such interruptions during the last few years, because in times of crisis carriers have managed to find alternative routes, no real progress has been achieved in improving the supply lines between Rwanda and the Indian Ocean ports. Owing to this situation, transportation costs are very high and product costs CIF-Rwanda are more than double the international prices on the coast.

4.2 Despite these difficulties, consumption of petroleum products has risen steadily, from 50,000 tons in 1981 to over 100,000 tons in 1987, an average annual growth of 12.5%. This is the most notable characteristic of the sector. It is explained by the relatively low absolute level of consumption per capita, only around 15 kg/year. The upward trend of consumption per capita can therefore be expected to continue even if the growth of the economy as a whole and of exports in particular are much slower. This prospect presents a double problem, calling for both financial and energy-related initiatives:

(a) measures to improve the country's external financial position, especially foreign exchange earnings, in the years ahead as part of the Government's overall efforts in this respect; and

(b) timely preparation of measures to: (a) improve utilization efficiency and (b) substitute national energy sources for oil products, so as to contain the growth of imports of oil products within reasonable limits.

Structure and Evolution of Demand

4.3 Like most of the weakly industrialized countries, Rwanda consumes much more white products (gasolines, kerosene, and diesel) than heavy fuel oils. In 1987 automobile fuels--gasoline and diesel--accounted for three-fourths of total consumption of oil products, kerosene 13%, and heavy fuel oil 11% (see Annex 2.1).

4.4 Heavy fuel oil is consumed only in a few industrial units, the largest of which is the MASHYUZA cement works. This unit, which has an annual capacity of 57,000 tons, entered into service in 1985 and reached full operational status in 1987, with a consumption of about 9,000 tons of fuel oil--nearly four times the total fuel oil consumption of the other industries. However, this substantial growth of demand for fuel oil in 1986-87 is an isolated event since no other industrial unit of comparable size is currently envisaged in Rwanda.

4.5 Petroleum products for domestic uses are liquefied petroleum gas (LPG) and kerosene, used mainly for lighting but also increasingly for cooking. Kerosene demand has risen very substantially over the last four years, from 2,134 tons in 1983 to 8,775 tons in 1987, an average growth of 42% a year. LPG use is growing more slowly, mainly because of its high price. The rapid growth of consumption of petroleum products for domestic uses reflects the pressing need of the people to improve their basic standard of living.

4.6 Consumption of aviation fuels has stagnated over the last few years. Because the jet fuel sold at Kigali is expensive, the international companies prefer to fuel their aircraft at Nairobi or other airports, where petroleum products are offered at more competitive prices. Use of aviation gasoline remains limited by the fairly low volume of local traffic.

4.7 The rapid growth of consumption of petroleum products over the past decade will very probably continue, provided that no significant change takes place in current economic and energy equilibria. The growth of consumption of petroleum products over the past years is not in fact the result of particularly vigorous economic activity but rather of developments in production methods and life style. The road network has been substantially improved and continues to be developed. The vehicle fleet has grown steadily, including during the last few years, and so far this trend shows no sign of slowing down.

Table 4.1: TREND OF NUMBER OF NEW VEHICLE REGISTRATIONS

	1985	1986	1987
Private cars	381	457	393
Utility vehicles, minibuses	1,021	992	1,054
Trucks	148	110	146
Consumption of fuel (t/year) a/	10,500	9,800	10,730

a/ Private car:20,000 km x 12 l/100 km = 1.8 t/year
Utility vehicle:50,000 km x 18 l/100 km = 7.2 t/year
Truck:50,000 km x 40 l/100 km = 16.8 t/year

Source: Banque Nationale du Rwanda.

4.8 If current trends persist, total consumption of petroleum products in Rwanda will be well over 300,000 tons/year by the end of the century; it seems this would be difficult for the balance of payments to support. That being so, it would probably be more realistic to anticipate a lower growth in consumption in response to financial constraints and appropriate energy policy measures (possible measures are discussed later in the chapter).

Organization of the Petroleum Sector

4.9 Petroleum products are imported and distributed by six companies. One of these, PETRORWANDA, is majority-owned by the Government, two are subsidiaries of the large international companies (SHELL and BP-FINA) and three belong to Rwandan private entrepreneurs. The largest is one of the latter, ERP (Entreprise Rwandaise de Pétrole), which holds 40% of the market. The state enterprise PETRORWANDA, which led until 1983, is now in second place, with 24% of the market. The sector is organized along a market-oriented line: the six companies compete vigorously to defend or expand their market shares; they are also exposed to indirect competition from several other companies which often import petroleum products for their own consumption. PETRORWANDA joins in the competition without any special privilege. Entrepreneurs wishing to enter this sector of activity do not have to comply with any specific requirements but only with the general conditions governing the establishment and operation of commercial companies.

4.10 The Government reserves to itself a role of supervision and control of this sector, using three levers in particular: (a) price control; (b) regulation of transportation, and (c) constitution of buffer stocks. Moreover, the creation of the mixed-capital enterprise PETRORWANDA, with majority state participation, meets the Government's desire to gain a better insight into the oil market mechanism and cost structure and to possess means of intervening directly, if necessary, for example in management of buffer stocks and service of regions inadequately covered by the other companies.

Supply and Distribution

4.11 Importers freely negotiate purchase prices with their suppliers, most of which are Kenyan subsidiaries of large international companies, or oil trading companies, present in Kenya or Tanzania. Other formulas are also used, including direct purchase from Arabian-Persian Gulf suppliers, in association with Kenyan or Ugandan companies. The diversity of purchase formulas used is dictated by the competition among importers, who seek lowest-cost solutions to be able to compete on the domestic market and preserve their profit margins. In this competition each importer acts independently. The Government confines itself to monitoring invoiced prices to detect any anomalies among the FOB prices of the various importers. This system operates fairly satisfactorily and, to judge from comparison with international prices quoted in the East African coast ports, results in FOB prices that under the circumstances seem reasonable (see Annex 2.2).

4.12 On the other hand, constituting a small market in itself and being served by a number of importers each purchasing modest quantities, Rwanda might conceivably benefit from a different approach: that of coordinating purchases to reduce the price and of optimizing deliveries to lower freight costs. A study, managed by the World Bank, with the objective of rationalizing the supply of petroleum in Sub-Saharan Africa subregions, is expected to commence shortly. The outcome of the study may well be solutions which could greatly benefit small land-locked countries like Rwanda.

4.13 Imported petroleum products can reach Rwanda by several routes. The most heavily used route passes through the port of Mombasa, the Mombasa-Nairobi pipeline, 485 km, and by truck

Nairobi-Kampala-Kigali, 1,250 km. A variant of this route, used for example during the times of unrest in Uganda, runs from Nairobi via the south of Lake Victoria, across Tanzania. Another route passes only through Tanzania, from the port of Dar es Salaam, either directly by road to Kigali, about 1,560 km, or by rail from Dar es Salaam to Tabora and Isaka, then by truck from Isaka to Kigali, about 600 km. The latter route is not yet extensively used because the road modernization works between Isaka and the Rwanda frontier have not yet been completed. It could however become a heavily traveled and perhaps less expensive route in the future if the planned improvements are carried out. 4/ Increased use of routes via Tanzania should also improve the opportunity for petroleum product purchases from less expensive sources of supply in the Arabian-Persian Gulf. The various routes are used alternately, depending on circumstances: state of the roads, security, price of petroleum products at Mombasa and Dar es Salaam, various transit duties, transportation cost on the various sections, and so on. In the present situation, transportation cost accounts for over 50% of the price CIF-Kigali. It is US$260-300/ton for the main section via Nairobi-Kampala (US$40-50/ton for the Mombasa-Nairobi pipeline, plus US$220-250/ton for transportation by truck Nairobi-Kigali) and US$230-280/ton for the routes starting at Dar es Salaam. These prices are financial, however, and do not properly reflect the economic costs of transportation for the alternative routes. It is likely that the real cost difference is greater than mentioned (real costs via Tanzania being lower), but the magnitude of it is not yet known. One of the outcomes of the study referred to in footnote 4 should be greater transparency with respect to cost components in the build-up of petroleum prices, as a basis for price reductions once the bottlenecks in the transportation system are reduced.

4.14 Since strengthening the transportation system is an important safety factor for supplying Rwanda with petroleum products, the Government has developed a policy to encourage the building up of a large fleet of tank trucks able to ensure a sustained import flow under all conditions. This policy includes, in particular:

(a) setting the tank truck transportation cost between Nairobi and Kigali (or equivalent), included in the oil price structure, at a fairly high level, to ensure that the carriers are well remunerated;

(b) measures aimed at creating powerful and well organized international transport enterprises.

The regulations drawn up in 1985-86 restrict international transport operations to companies that have obtained the status of "authorized carrier." To do this, a company must: (a) possess a fleet of at least 20 trucks; (b) possess the necessary facilities in Rwanda (offices, garages, parking space); and (c) be organized as a joint-stock company at least 51% of whose capital is held by Rwandan shareholders. Authorized carriers can subcontract their transport operations to small private Rwandan

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4/ *Opening of this road to general freight as well as to oil products is a specific project which includes improvements in the port of Dar es Salaam, rehabilitation of the railway, a rail/road terminal with storage depot at Issaka, and modernization of the Issaka-Rusumo-Kigali road (IDA: Tanzania Petroleum Sector Rehabilitation Project). It is uncertain at this stage, however, to what extent this route will actually be used for transporting products to Rwanda, assuming transit fees that fully reflect the costs of the improvements will be charged.*

carriers and, under certain conditions, even to foreign carriers. Small carriers operating as subcontractors are remunerated at the official tariff minus a 5% commission withheld by the authorized carrier.

4.15 This policy has encouraged investment by Rwandans in transportation facilities, which have expanded appreciably over the last two years. At the end of 1987, Rwanda possessed a fleet of 137 tank trucks, of which only 29 belonged to the two "authorized carriers": STIR, a mixed-capital company with Government majority shareholding, and CORWACO, a totally private company.

Table 4.2: RWANDAN INTERNATIONAL TRANSPORT TRUCK FLEET (December 31, 1987)

	STIR	CORWACO	Subcon-tractors	Total
Tank trucks	6	23	108	137
General freight	57	6	365	428
Total	63	29	473	565

Source: Direction Générale des Transports.

In 1988 a third company, SOGETI, with 20 large-capacity (60 m^3) tank trucks, became an authorized carrier. The static total tank truck capacity is currently about 4,800 m^3, equivalent to a conventional haulage capacity on the Nairobi-Kigali route of 115,000 m^3/year, i.e., of the same order of magnitude as Rwanda's total petroleum product imports. However, this capacity is excessive in current circumstances since some 20-25% of traffic is carried by foreign (notably Kenyan and Tanzanian) carriers, which are cheaper. The Rwandan trucks are now beginning to be under-utilized, so that the investments made to develop the fleet cannot obtain the expected return. This means that the Government's protectionist policy, through which the goal of strengthening the national transportation fleet has been achieved, also has some disadvantages. To get themselves out of this difficulty, Rwandan carriers will now have to gear themselves more and more to neighboring country markets, striving to be more competitive. Moreover, to maintain their position on the domestic market they are beginning to grant discounts on the official prices, which means that transport price control no longer serves any purpose. The Government should therefore abandon it; that would help: (a) to clarify the situation for the carriers and spur them to greater efficiency efforts, and (b) to lower the CIF price of imported petroleum products.

4.16 A further step towards deregulating the transport system would be to consider abolishing the system of authorized carriers altogether. The total Rwandan truck fleet is relatively large and a major share of it is owned by small carriers who pay to the authorized companies a commission which quite possibly only adds to the total costs of transport. Since the country now appears to have achieved its aim at having a fleet of tank-trucks that maintains a sustained flow of petroleum products, the Government should consider abandoning the present barriers to entry together with the transport price control.

4.17 Petroleum products are distributed through the station networks of the six companies and also directly to the major customers. PETRORWANDA has the most highly developed network, with about 30 stations distributed throughout the country. ERP, the leader in terms of sales volume, possesses 23 stations located in the major traffic centers. Average monthly flows distributed per station, 50-100 m^3 depending on the company, represent a satisfactory level of performance, comparable with the European distribution networks (France: 75 m^3/month, FRG: 135, Italy: 38, United Kingdom 80). Some of the stations belong to the companies and operate with salaried personnel; others belong to private managers with an exclusive contract with one oil company. Each company pursues its own policy in this respect. PETRORWANDA, for example, uses both formulas but over the last few years has given preference to management contracts and tends to limit the number of stations belonging to it in order to avoid inflating its administrative expenses.

4.18 The oil companies possess modest storage capacity, totaling 8,000 m^3 in the distribution stations (ERP: 2,000 m^3; BP-FINA: 1,400; PETRORWANDA 3,000; and the three other companies--SHELL, SGP, and RWANDA PETROLGAZ--1,400 m^3); however, these capacities are sufficient to ensure regular supply of consumers when road transportation functions normally. But the companies are not protected against the hazards of international transport and when difficulties arise suffer shortfalls which can influence their market position. In serious situations, the Government intervenes by authorizing drawdown of its buffer stocks. For relatively unimportant incidents, however, the companies have to fend for themselves. With this in mind, ERP, in order to consolidate its position of market leader, decided to build a 5,000 m^3 depot in 1988 which will be the first purely operational large depot. ERP could allow the other companies to use this storage facility for a fee.

Buffer Stocks

4.19 Apart from the operational stocks referred to above, Rwanda possesses Government-owned buffer stocks totaling 10,000 m^3. These stocks were set up in 1979 when the country had to be supplied by air because road communications were cut for 8 months. PETRORWANDA is responsible for physical management of the government stocks but does not have the right to use them except in case of crisis and then only with the Government's permission. These stocks have already served on several occasions to tide over periods when road communications were cut and have amply demonstrated their usefulness. In view of the growth of consumption the Government decided to construct another 15,000 m^3 of storage capacity, distributed between two depots: GATSATA (3 x 3,660 m^3) near Kigali, and Butare (2 x 1,950 m^3). These depots, built in 1988 with the help of a FF 62 million loan by the French Caisse Centrale de Coopération Economique (CCCE) 5/, will give Rwanda 25,000 m^3 of buffer stock storage, i.e., 2.4 months' consumption at the 1988 demand level. A buffer stock of this size is normal, even for countries better located geographically than Rwanda, and seems to be well in line with its current needs. The Government will now have to resolve the problem of how to finance the petroleum products (at an import value of approximately US$5 million) to be stored in the new tanks. A long-term loan on concessional terms seems to be the solution that would have the least impact on the already high cost of petroleum products distributed in Rwanda. However, the Government will have to define a policy for financing buffer stocks since they will have to be further increased in the

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5/ *20-year loan with seven years of grace, interest at 3% p.a.*

future in step with the growth of consumption, unless alternative transportation routes that effectively increase the safety of supply are constructed. To finance the stocks which add to the total cost of supply of petroleum products, the Government should consider levying a tax. This could be introduced as a part of a general taxation and price revision (see para. 4.24).

4.20 Filling of substantial new stockpiles should be preceded by contingency planning for their eventual utilization and replenishment related to a possible interruption in surface transportation. While it is impossible to foresee the conditions under which a supply interruption would occur with sufficient precision to prepare a detailed plan, it is easier to make adjustments to a pre-set plan during a crisis than to start with no plan. Contingency planning might include, inter alia, identification of key imported products, key import-dependent activities, and drawing up a supply strategy to deal with such a situation.

Taxation and Prices

4.21 Oil prices in Rwanda are only partly controlled by the Government: for automobile gasoline and diesel a maximum selling price is laid down but for other products it is uncontrolled. In practice the companies always grant discounts (2-5% or even more) to their large customers in order to retain them. These discounts are one of the major weapons in the competition between the companies. Some large customers--airport, cement works, government offices, army, etc.--even invite bids in order to conclude supply contracts with the company offering the best price and service. The companies sometimes even offer discounts at the pump to attract small customers.

4.22 The Government's petroleum price policy is to keep the selling price constant while adapting the level of taxation to compensate for changes in the world market price. Maximum prices at the pump had not changed since 1981 and therefore still reflect record international market prices (the 1990 adjustment mainly compensated the devaluation). The Government has raised taxation in step with falling world market prices, notably during 1984 through 1987, with the result that it is currently fairly high (automobile gasoline 44% of selling price, diesel 46%, but kerosene only 6.2% and fuel oil 14.6% (see Annex 2.6). Annex 2.4 depicts the development of taxation for the two major fuels, gasoline and diesel. Annex 2.5 shows all the taxes currently applied. The fairly marked discrepancy in taxation between the different products reflects the Government's wish to favor certain types of consumers. This differentiation has a direct impact on the development of the country's general energy demand structure and thereby represents an energy policy issue. In this respect, reference is made to the low taxation of kerosene and fuel oil and to the question of whether the intended beneficiaries actually derive the advantage of the low tax rates (see Annex 2.6 which shows a high wholesale margin particularly for kerosene).

4.23 Until the recent devaluation, the Rwanda Franc was considerably overvalued. This implies a real level of taxation that is lower than the rates quoted in para. 4.22 and which, for certain products, may even be negative (subsidy). The rapid increase in consumption of petroleum products and, to a certain extent, inflation, in the '80s may support the view that prices are not so high, after all, as they first may appear to be. For balance of payments reasons or in order to reduce possible inefficiencies in consumption, raising taxes and the level of petroleum product prices could be seen as desirable. On the other hand applying higher taxes to prices that already reflect economic costs to the country of importing and distributing these products might lead to sub-optimal consumption from a national point of view. High prices also have another disadvantages: they generate clandestine imports of petroleum products from neighboring countries where prices are lower. This negative situation has apparently been developing in Rwanda over the last years and seems likely to become quite serious unless suitable measures are taken. An estimated 1,000-2,000 tons of petroleum products, mainly diesel, are currently smuggled into Rwanda each month (equalling possibly between 1/4 and 1/3 of total diesel consumption).

4.24 Considering that, until the 1990 adjustment, prices of major petroleum products had remained unchanged since 1981 and that initial justifications for their level and structure may quite conceivably no longer be valid, it is recommended that a study be carried out of petroleum product pricing and taxation. The new price structure should reflect the economic cost of petroleum products in absolute and relative terms. The revision should take into consideration the exchange rate situation of the Rwanda Franc and other factors mentioned in the preceding paragraph, as well as the price relationship among petroleum products, on the one hand, and between relevant petroleum products and other fuels, on the other hand.

4.25 Dating largely from 1987 there has been a proliferation of imports exempted from duty. In 1987 duty-free imports represented a high proportion of total import volume (over 50% in the cases of diesel and fuel oil); this obviously allows scope for illicit traffic in duty-free products (see Annex 2.2). The oil companies would like to import products for stockpiling free of duty. In view of the problem of financing the 15,000 m^3 of new buffer stocks (see para. 4.19 above), the Government might be tempted to grant the companies this concession in return for an obligation to deposit in the buffer stocks specified quantities of products, pro rata to each company's volume of operations. This apparently logical formula involves very complicated management of these stocks and the risk of generating other forms of tax evasion. The mission recommends that the Government not grant these tax exemptions but on the contrary limit duty-free import authorizations to very narrowly defined cases. A much better way would be for the Treasury to refund the part of the taxes paid by consumers entitled to exemption against presentation of documents testifying to actual consumption of the quantities concerned. For some uses, for example consumption relating to public contracts, duty exemption should simply be abolished.

Institutions and Petroleum Policy

4.26 The Government's petroleum policy is defined fairly clearly by, in particular: (a) its market-oriented approach to the organization of the sector; (b) its concern to ensure security of supply, reflected in the measures taken to strengthen transportation facilities and set up buffer stocks, and (c) fairly high taxation (at least in nominal terms) and control of the maximum prices of the major fuels. However, it is noted that this policy is formulated and applied not by the energy sector agencies but by those responsible for economic and financial matters. The Direction Générale de l'Energie (DGE) has very little involvement in petroleum questions, limiting its activity in this sector to (not very efficient) statistical monitoring. This situation is undesirable and results in an incorrect approach to energy problems in other sectors (electricity, firewood, renewable sources of energy). The mission considers it essential that the DGE be made responsible for all aspects of petroleum policy. In some areas, such as taxation, import financing and price control, the DGE will of course have to work closely with the economic and financial agencies, taking care to tailor the requirements of the Government's economic and financial policy to the specific constraints of the energy sector as a whole. But in matters of development strategy, buffer stocks, measures to rationalize consumption, energy substitutes for petroleum products, and so on, the DGE should play the major role in supervising activities and designing policies for proposal to the Government.

4.27 An important activity that the Government has not adequately developed is monitoring of the international petroleum market. This work is currently limited to recording the FOB prices actually paid by Rwandan importers and verifying by simply checking them against the prices paid by other importers. This level of monitoring seems to be adequate to avoid clandestine operations but not to evaluate or help improve the importers' commercial performance. Moreover, to be able systematically to adjust the level of taxation to changes in external prices, the Government needs up-dated information on international oil market data and trends, and this very promptly in order not to delay tax change decisions and thereby put the oil companies in an excessively unfavorable position when external prices rise (or an excessively favorable one when prices fall). For that purpose, it is proposed that the Directorate of Energy be given the responsibility for monitoring petroleum products prices as part of the increased involvement in petroleum matters.

4.28 In addition to taxation, price control and security of supply, the Government's petroleum policy will have to include specific action programs to find suitable solutions to the problems that characterize Rwanda's energy system, particularly:

(a) bringing consumption of energy and particularly of petroleum products under control by eliminating waste and reducing specific consumption in user facilities;

(b) promoting substitute energy sources to replace petroleum products by local forms of energy where this makes good economic and energy sense.

The Government has already taken certain measures under both these headings but they need to be fitted into coherent programs and monitored firmly and methodically.

Reduction of Specific Consumption

4.29 A study of energy consumption in 15 of the largest industrial enterprises was carried out in 1986 on the initiative of the EGL and with the support of French Cooperation. The study identified a number of possible measures to improve specific efficiency of energy end-use, particularly for fuel oil and diesel. These measures--of the conventional type (reduction of excess air, preheating, etc.)--could lead to savings estimated at 450 tons of fuel oil and diesel a year (3-4% of actual consumption). A cement works study conducted in 1987 in connection with utilization of Lake Kivu gas, demonstrated the high specific energy consumption in the MASHYUZA cement works: about 200 kg of fuel oil per ton of cement, explained partly by the technology used (wet process), but also by the lack of close monitoring of plant operations. A follow-up of these studies could result in a significant reduction in industrial fuel consumption through improvement of the plant, for example by installing metering and automatic regulation devices. The Government could encourage such action through measures of two kinds:

(a) increasing the relatively low taxation of fuel oil to encourage industrial operators to make energy savings; such a measure should, however, be considered in the broader context of a study of petroleum products taxation, as mentioned previously;

(b) granting of financial support for expert studies and advisory assistance and to help industrial operators acquire metering and regulating devices to bring energy-using processes under control.

4.30 With regard particularly to the cement industry, which is a large energy consumer, it is pointed out that current production capacity is just adequate to meet demand. Cement demand will continue to rise, however, reaching 75-125,000 tons by the end of the century. This could lead the Government to study alternative ways of coping with this growth. It is recommended that, in assessing these alternatives, the Government take the energy factor carefully into consideration by studying, in particular, the possibility of using the "dry" process, with its much smaller specific consumption figures (60-80 kg of fuel oil per ton of cement).

4.31 No specific measures have been taken so far to reduce specific gasoline and diesel consumption rates. Although the automobile fleet is relatively new (average age 3.5 years), transportation operators would probably be receptive to initiatives to improve fuel consumption through: (a) obligatory periodic checking of carburetors, (b) promotion of economical driving, and (c) possibly "dieselization" of fleet (trucks and buses). The most suitable ways of initiating such activities would have to be defined jointly by the DGE and the Direction des Transports (DT), taking advantage of the ongoing programs of support for the transportation sector.

Replacement of Petroleum Products by Other Forms of Energy

4.32 The relatively high level of petroleum product prices in Rwanda means that certain types of energy substitution are feasible there that would not be economical in other countries with easier access to petroleum product supply sources. Measures that were envisaged include the use of: (a) Lake Kivu methane gas through various technical processes, including the manufacture of substitute fuels, such as CNG which could replace, for example, LPG, kerosene or fuel oil (see Chapter VI); (b) peat or coal from the Kalemie mine (Zaire) in some industries to replace fuel oil; (c) fuel alcohol, mixed with gasoline; and (d) electricity in industrial boilers and furnaces instead of fuel oil or diesel(see para. 4.34).

4.33 Production of fuel alcohol has been studied under a community project of the Great Lakes countries promoted by EGL consisting of the manufacture of about 2,700 m^3/year of fuel ethanol in a distillery to be built near the Kiliba sugar mill in Zaire. This output would be allocated among the three countries--Zaire, Rwanda, and Burundi--for mixture, in a ratio of about 10%, with the gasoline distributed in the region. A feasibility study completed in 1986 put the investment cost at US$4.1 million (1985) and concluded that the project was remunerative assuming that the alcohol could be sold to the oil companies at about US$400/m³. For the operation to be truly profitable, therefore, the CIF price of gasoline imported into the region would have to exceed US$450/m³. Since the CIF-Kigali price of gasoline is currently US$374/m³ (see Annex 2.3), the project is not, at present, economically or financially attractive. However, it should be kept in mind for future implementation if oil market conditions change.

4.34 A program of electrification of industrial boilers and furnaces in the Great Lakes countries has been studied, also by EGL, as part of the package of measures to make the Ruzizi II hydroelectric power station economically efficient. It was found that this program--which was originally based on the concept of a large electricity surplus in the grid--would be economically interesting if the power were offered at its (short-run) marginal cost. Subsequent studies were considerably more cautious as to the timeliness of installing electric boilers, since they showed that the generating capacity of Ruzizi II, first phase, would approach saturation sooner than anticipated. As discussed in Chapter V, under the circumstances, the conversions appear to have no economic or financial justifications. A combination of higher oil prices and/or electric power based on regional low cost development would be required to justify the electrification program.

Summary of Principal Recommendations

4.35 The principal recommendations of the mission are as follows:

(a) The Government should consider the outcome of a study, managed by the World Bank and expected to commence shortly, with the objective of rationalizing the supply of petroleum in Sub-Saharan Africa subregions as an alternative to the present practice of independent purchases in small quantities;

(b) The Government should consider abandoning the present system of authorized carriers, on the grounds that the country now has a sufficient fleet of tank trucks and that the present system quite possibly contributes only to increasing total transport costs;

(c) Since the tank truck fleet is beginning to have surplus capacity, the Government should now proceed to deregulate transportation prices. This will stimulate Rwandan carriers to improve their efficiency and their ability to compete on neighboring country markets. It will at the same time help lower the CIF price of imported petroleum products;

(d) The Government should develop a contingency plan to deal with supply interruptions identifying, inter alia, key import-dependent activities and drawing up a supply strategy to deal with such situations. It should also define a policy for financing future increases in buffer stocks and consider an earmarked tax to cover storage costs;

(e) It is recommended that the Directorate of Energy's area of responsibility should be expanded to encompass the petroleum sector, including the formulation and follow-up of petroleum policy, in cooperation with other relevant government agencies. To be able to systematically adjust the level of taxation to changes in external prices, a closer monitoring of petroleum prices is called for;

(f) A study should be carried out on taxation and pricing of petroleum products, giving due consideration to the economic cost both in absolute and relative terms. The level and structure should be reviewed on the background of an exchange rate situation and of the need to: (i) limit inefficient consumption of imported products for economic, especially balance of payments reasons, (ii) reduce clandestine imports from neighboring countries, (iii) consider the fiscal revenue potential of petroleum taxes, (iv) consider substitution effects between petroleum products and vis-à-vis other fuel sources and (v) evaluate to which extent intended beneficiaries actually derive the advantage of lower taxes (e.g., on kerosene). A comprehensive approach to the pricing and taxation issue would call for collaboration between the Energy Directorate and the agencies responsible for macro-economic decisions making;

(g) The Government should draw up and implement specialized programs for: (i) improving the efficiency of utilization of petroleum products, and (ii) replacing them by other forms of energy wherever this is reasonable and economic. These programs will have to include all phases: study, definition of feasible projects, and promotion of their execution. Among the various development directions explored up to now, the most promising appear to be extraction of Lake Kivu methane gas for alternative uses, the type and size of which remain to be defined.

V. ELECTRIC POWER

Demand for Electricity: Past and Future Trends

5.1 The consumption of electricity reached a level of 105.2 Gigawatt per hour (GWh) in 1987, representing a per capita consumption of only 16 kWh, one of the lowest values in the world. In spite of an average annual rate of growth in the number of connections of 17% in the last seven years, still only a small fraction of the total population of the country (1.4%) uses electricity. All major urban centers are supplied by the national grid, but only a very small percentage of their respective populations actually uses electricity. In 1987, Kigali's consumption represented 60% of the national total, yet less than 12% of its population is connected to the power network.

Table 5.1: CONSUMPTION BY CONSUMER CATEGORY
(GWh)

	1980	1981	1982	1983	1984	1985	1986	1987	Growth Rates (% p.a.) 1980-87	1985-87
Industrial	30.2	32.5	34.7	34.7	35.8	36.8	35.1	36.5	2.7	2.4
Commercial	7.2	8.5	13.4	11.3	14.3	14.6	14.3	14.3	10.8	0.7
Residential	12.5	14.5	13.5	14.3	17.5	17.7	20.0	23.7	9.6	15.8
Public Services	6.0	7.2	9.4	12.4	13.2	21.2	22.5	24.1	22.4	6.6
ELECTROGAZ	1.4	1.1	2.4	2.6	3.1	4.2	3.2	6.1	23.4	20.0
Total	57.3	63.8	73.4	75.3	83.9	92.5	95.1	105.2	9.0	6.7

Source: ELECTROGAZ.

5.2 Electricity consumption, as measured by sales to consumers connected to the public supply system, rose at an average annual rate of 9.0% in the period 1980-87 (Table 5.1). Year-to-year growth rates were in general above 10%, with the exception of 1982-83 and 1985-86 when they only reached 2.7% and 2.8% respectively. There is no close correlation between the growth of electricity consumption and the growth of GDP on a year-to-year basis. For example, the reduction in the rate of economic growth in 1982 was accompanied by an exceptionally high increase in electricity consumption. A similar phenomenon occurred in 1984, when GDP is estimated to have declined by 4.3%, while electricity consumption rose by 11.3%.

5.3 The distribution of consumption by consumer categories indicates that important relative changes have occurred during the 1980s. The participation of the industrial sector declined from 52.3% in 1980 to 34.7% in 1987, while the public services sector increased its share from 12.8% to 28.7%, in part due to increased investment in public lighting. Residential and commercial sectors have had very small changes in their shares, which in 1987 reached 22.5% and 14.1% respectively. These changes in distribution are a reflection of the sectoral rates of growth, which indicate a very low annual rate of growth for the industrial sector (2.7%) and slightly above average rates for the residential and commercial sectors (9.6% and 10.8%). The growth in residential and public sector consumption has also had an important impact on the growth in peak demand. Peak demand grew an average of 11% annually for the period 1984-87, from 18 MW in 1984 to 24.9 MW in 1987. The past practice of developing high standard public lighting should be reexamined, and energy efficient designs considered instead to avoid investments in costly new plant capacity with limited benefits. Tariff structure should also be reviewed to determine whether some of the residential consumption contributing to the peak can be displaced to other time periods.

5.4 Within the electric network there are nine consumers which use more than 1 GWh/year, collectively accounting for about 30% of total consumption. The largest consumer is the Deutsche Welle radio station which consumes around 8 GWh/year. Others are BRALIRWA (brewery), MASHYUZA (cement), the waterworks at Mugesera, and several tea factories (SHAGASHA, MULINDI, CYOHOHA). In addition, 13 users consume more than 500 MWh and represent another 10% of the total. Among them are SULFORWANDA (soaps and detergents), RWANDEX (coffee), the army camp at Kanombe, the university at Butare, and several hotels in Kigali. The total number of users supplied by medium voltage (MV) distribution lines is 162 accounting for collective consumption of 53.2 GWh or 50.6% of the total.

5.5 The number of low voltage (LV) consumers has increased from 4,366 in 1980 to 13,355 in 1987, with an average annual growth rate of 17.3%. Assuming that the number of residential and commercial users of electricity is equal to the number of LV users, consumption per unit has declined from 4,521 kWh/year in 1980 to 2,889 kWh/year in 1987. This phenomenon is explained by the fact that electrification expansion to new regions and residences is progressively integrating areas of lesser development and lower incomes. This trend is likely to continue through the long-term given the low proportion of the population which has access to electricity.

5.6 Increasing the population's access to electricity is among the most important objectives of the Rwandese Government for the electricity sector. First priority should be given to expanding connections in areas where service is already available. However, a major obstacle to expanding service to new consumers even in areas already served by the urban grid, is the high cost of an electricity connection. According to the existing regulations, consumers must pay all the costs of the connection study, the equipment to be installed and the works to be executed, plus 10%, normally in one installment when the connection is contracted. While an effort was made in January 1988 to lower this cost somewhat by decreasing the surcharge from 15% to the present 10%, it is estimated that the average connection charge is still about US$750, while GNP per capita in the country is only about US$290. The high cost of connections is in part explained by the overly demanding technical specifications of the equipment used (tri-phase connections have been used in the past for all LV consumers), excessive use of underground cables in urban areas and low efficiency of the working teams (ELECTROGAZ' own staff connect new customers rather than using private electrical contractors). For electrification to be expanded beyond the larger, higher income consumers, more appropriate standards should be introduced, efficiency should be controlled and the connection charges should be spread over time using a credit mechanism combined with lifeline tariffs when these are justified. The regulations which took effect in January 1988 in fact allow special arrangements for term payment of connection charges to be made between new consumers and ELECTROGAZ at the latter's discretion, however, the level of need for such arrangements is high and likely to increase the administrative and financial burden on ELECTROGAZ if all demand for these arrangements is to be met. ELECTROGAZ has extended the repayment period to clients of limited risk, but it would be preferable to develop a policy for term payments and lifeline rates supported by donor funding for connections which would relieve ELECTROGAZ of some cash-flow risks and allow more new consumers to benefit.

5.7 Before undertaking distribution expansion into new areas, low cost distribution systems should be examined. Testing of one or more such schemes on a pilot basis should be undertaken, particularly before proceeding with any major rural electrification program.

Future Demand Growth

5.8 Seven different projections of future electricity consumption have been prepared for Rwanda, as each consultant who has undertaken a pre-feasibility or a feasibility study has developed a forecast of demand projections specific to the justification of the investment. The oldest and most complete study is the one published in 1983 by the Société Nationale d'Etudes de Projets (BUNEP) in conjunction with the Ecole Polytechnique Fédérale de Lausanne (EPFL) as part of a comprehensive energy Master Plan. This Study was based on 1980 data, and when its projections are compared to actual consumption for 1987, they show an overestimation of 16.1 GWh, or 15.3% of actual consumption. The consumption of electricity in the industrial sector has grown at a much smaller rate than projected by the BUNEP/EPFL study, while the residential sector has exceeded all expectations. Given the elapsed time and the noted differences, the demand projections of the BUNEP/EPFL study are no longer useful.

5.9 Projections established by various engineering consultants vary between 107.0 GWh and 184.0 GWh for 1990 and between 128.7 GWh and 292.2 GWh in 1995 (actual consumption in 1987 was 105.2 GWh). The spread among the different estimations is 72% in 1990 and 127% in 1995, which presents a difficult problem of choice and consistency. In recognition of the need to update the BUNEP/EPFL study and develop a reliable set of data for investment and policy decision-making, the Government of Rwanda has decided to prepare a new electricity Master Plan, which will be based on rigorously established projections of demand. Since these new projections will not be available until the second-half of 1991 at the least, interim demand projections were prepared in the light of recent consumption patterns, expansion plans of key consumers and varying general economic trends. It should be noted that these interim projections are not a substitute for the detailed Master Plan projections whose preparation should be given high priority in order that key investment decisions can be taken on the basis of complete information.

5.10 Annex 3.1 gives the projected consumption of electricity under three different scenarios. Scenario A represents a low growth situation where total consumption increases at an average rate of 6.0% between 1987-2000. The scenario was developed assuming a rate of growth of industrial electricity consumption of 3.0% per year, which approximates the historical average rather than projected GDP growth since no correlation has been found with the latter variable; an increase in the number of residential and commercial consumers of 10% per year, or well below past trends; a gradual decrease in unit consumption of these users to 2,500 kWh in 1989 and a growth of public sector consumption of 5% per year as controls on the expansion of this sector tighten and major public lighting programs come to an end. In Scenario B, the number of residential and commercial users increases at an annual rate of 15%, maintaining the high growth rates of the recent past, while all other assumptions are maintained. The resulting overall growth of consumption is 8.8% per year between 1987-2000, which indicates that demand projections are very sensitive to increases in the number of electricity connections. Scenario C is a high growth case where industrial electricity consumption increases at 5% per year, the number of residential and commercial users at 15% per year while unit consumption of these users is kept constant at 2,800 kWh and public consumption grows at 7% per year. The average growth rate in this scenario is 10.2% between 1987-2000.

5.11 Under the described scenarios, total electricity consumption is projected to be between 119 GWh and 136 GWh in 1990 and between 162 GWh and 220 GWh in 1995. Assuming that total losses in the electrical network would decline slightly from their 1987 level of 17% to reach 16% in 1990 and remain constant at a conservative but still undesirably high level of 14% after that year, the required generation would be between 142 GWh and 162 GWh in 1990 and between 189 GWh and 256 GWh in 1995. While it is expected that actual values will be within these ranges, it must be noted that uncertainties are greater on the evolution of public consumption and on the number of new connections that will be undertaken since, if past practice continues, both will be subject to the revenue generation constraints of government fiscal policy and of ELECTROGAZ' rates.

5.12 Energy and capacity balances for Rwanda were calculated taking the medium growth demand Scenario B as the most likely alternative (Annex 3.2). For this purpose, the guaranteed energy of the domestic plants (Ntaruka, Mukungwa I, Gisenyi, and Gihira) is estimated as 8[illegible].4 GWh. The results indicate that Rwanda would need to import 53.5 GWh in 1988, that is 39% of the energy required by its system. This figure may be an overestimation because in 1987 domestic plants were able to produce 108.3 GWh, which is substantially above the estimated guaranteed energy. The operation of Ruzizi II in 1989, of which Rwanda owns one third of the energy to be produced, will reduce import requirements to 11.1 GWh in 1989. Assuming that no new domestic plants are built and that the third unit of Ruzizi II is operational in 1995, imports reach a peak of 75.7 GWh in 1994, which is 37% of the energy required by the country. The third 13.3 MW unit of Ruzizi II, to which Rwanda would also have a one-third claim, allows the country to maintain until 1995, almost the same absolute level of electricity imports as in 1994.

5.13 Rwanda has in the past imported between 10% and 19% of its electricity needs from Ruzizi I in Zaire (para. 5.18). In 1989, two units of the Ruzizi II plant, owned one-third by Rwanda, came on stream capable of producing 140 GWh annually which reduced the Ruzizi I imports. To examine whether Rwanda will continue to have adequate power available through recourse to imports from the regional interconnected network, a demand and supply balance for the Great Lakes region interconnected network was established (Annex 3.3). Based on the most likely rate of growth of electricity demand in Burundi and Zaire's Kivu region (drawn from recently completed national Master Plans), the import requirements of Rwanda can be satisfied until 1995. As a matter of fact, there would be a substantial surplus of electric energy in the region between 1989 and 1992. With the addition of the third unit of the Ruzizi II plant only in 1995, the supply situation would be tight in 1994 (surplus of only 1.2 GWh), but would be reasonable in 1995; this would seem to indicate that a one-year advancement in the operation of the third unit of Ruzizi II may be justified. In 1996, a deficit of energy occurs, requiring the coming on stream of an additional power plant to supply the region.

5.14 The capacity balances for Rwanda that are presented in Section 4 of Annex 3.2 indicate that peak demand would not be a constraint before 1996. The existing domestic plants plus one-third of the capacity of Ruzizi II satisfy all the peak power requirements for the period 1989-1992. For 1993-95 reinforcements from foreign sources are needed, with a maximum of 4.7 MW in 1994. That year, the surplus capacity in Zaire from Ruzizi I and its share of Ruzizi II would be between 7.4 MW and 12.2 MW, which is enough to cover the deficit of Rwanda. The national system of Burundi would also have a surplus capacity in 1994 and therefore will contribute to the satisfaction of the necessary reserve requirements of the interconnected system.

5.15 The foregoing demand analysis has excluded the conversion to electricity of more than a dozen of the three countries' existing industrial fuel-fired boilers which would require 44.5 GWh in 1990 rising to 89 GWh in 1998 (12.5 GWh and 27 GWh for Rwanda alone). While the Energie des Grands Lacs (EGL) has done several studies on this question and elaborated a program for this purpose, the conversions have no economic nor financial justification. Based on June 1988 electricity rates and petroleum product prices, the cost of producing an equivalent amount of energy in Rwanda is greater with electricity supplied from the national grid than with fuel-oil or gas-oil. The cost of producing a theoretical thermal unit (therm) with electricity is between RF 7.7 and RF 11.6, depending on the hours of utilization of the industry and its subscribed capacity, while the cost is RF 4.9 when fuel oil is used and RF 7.6 when diesel fuel is used. These costs exclude the investments costs in the new boilers. A comparison using economic prices will show greater differences since the economic cost of electricity is higher than the tariffs now in effect (para. 5.55) and the market price of petroleum products higher than their opportunity costs owing to the substantial taxes levied by the State.

5.16 The theoretical results indicated above were confirmed in visits to several industrial enterprises. None of them was interested in the conversion to electricity without a reduction in electricity rates and some subsidy for the purchase of the new electric boilers. Preferential electricity rates and subsidies appear to have no justification in Rwanda since Rwanda itself does not have a surplus of electric energy. While there will be a surplus in the Great Lakes region as a whole (para. 5.13), a reduction in rates in any of the countries in the region may be advantageous for only the short period of time until the surplus is eliminated; near the end of this period, in order to meet network rehabilitation and expansion needs, rates will have to be adjusted to the level of long-run marginal cost (LRMC), which are above present rates applied in all three countries. Were a program to convert industrial boilers to be implemented in Rwanda without the clear acceptance by the Government and industries that prices follow LRMC principles, it could have the undesirable effects of: (a) encouraging enterprises to undertake investment in conversion for which the expected benefits will not be realized or (b) requiring subsidization of industries either by the Government budget or other categories of consumers.

Supply of Electricity

5.17 Domestic generating facilities include four hydroelectric plants with a total installed capacity of 26.5 MW and four diesel plants with total power of 3.6 MW. Domestic supply to Rwanda's interconnected network, however, is essentially from the four hydroelectric stations. The Gatsata diesel station is available as standby for Kigali, with the remaining diesel plants out of service in order to minimize operating costs and especially petroleum product purchases. 82% of domestic production is from two power stations at Mukungwa (12.5 MW) and Ntaruka (11.3 MW). All hydroelectric stations have been constructed, or rehabilitated at least in part, since 1981 (Annex 3.4).

5.18 Rwanda has imported power since 1977 from Zaire's Ruzizi I plant. The proportion of imports has decreased steadily from 65% of total energy supplied to the network in 1980 (45 GWh) to about 15% in 1987 (19 GWh) (Annex 3.5). Contractual arrangements with Zaire would allow Rwanda to import about double the energy taken in 1987, but Rwanda has preferred to maximize the use of its domestic power plants, a policy which over time has had a negative effect on its hydrological resources, lowering in particular the level of Lake Bulera (para. 5.34). Rwanda purchased power from Zaire at an average cost of RF 2.74/kWh (US$0.034) in 1987, which is well below the corresponding average long run marginal cost (Annex 3.10). Given the relatively low cost of power imported from Zaire, Rwanda should weigh carefully the implications of operating its own hydro plants above the water replenishment capacity of its lakes, thereby depleting valuable natural resources, against the alternative of using the imported power already available to them.

5.19 Numerous autoproducers including tea factories, small agro-industries, hospitals, and missions operate their own diesel generating sets. Because of the high cost of diesel, operation of these privately-owned units are in many cases restricted to 2 to 9 hours per day. These producers often operate in areas which could not be supplied economically from an extension of the domestic interconnected network.

Organization of the Electricity Sector

5.20 ELECTROGAZ, the public entity responsible for the production, transmission, and distribution of electricity, water, and gas, was created by Decree Law No. 18 of 1976. ELECTROGAZ is a wholly Government-owned enterprise classified as an "établissement public" of commercial character. As such, it is also governed by a 1975 Organic Law which sets forth numerous a priori and a posteriori administrative controls for all public enterprises in this same judicial category. In 1990, the Government of Rwanda embarked on a Public Enterprise Reform study which - for ELECTROGAZ - resulted in a Performance Contract between Electrogaz and the Government of Rwanda. While awaiting the finalization of the 'Contract Plan', as envisioned by the structural adjustment program, the Government of Rwanda and Electrogaz agreed to sign a Performance Contract which should be valid for a 3 year period starting in 1991, and will include the following objectives: reducing the total personnel force to 60 connections per agent; recruiting and maintaining highly qualified personnel; developing basic and advanced training activities for personnel; providing before 9/30/91, a 3-year rolling investment program with financially and economically acceptable investments; and presenting the results of a study to separate water and electricity accounts before 6/30/92.

5.21 Administrative control of ELECTROGAZ is exercised by the Ministères des Travaux Publics, de l'Energie et de l'Eau (MINITRAPE). In the past, this control has sometimes been interventionist, and has overridden the statutory authority of ELECTROGAZ' Director to: (i) manage the enterprise's operations in accordance with standard utility practice; (ii) prepare and execute an operating and investment budget based on the enterprise's needs and the National Energy Policy; and (iii) recruit, reward or terminate the 40% of his personnel with civil servant status. While ELECTROGAZ has a Board of Directors comprised of presidentially appointed high level civil servants from five ministries, it appears not to function in accordance with standard management principles: the Board examines, notes, and advises only, deferring all decision-making to the appropriate ministry.

5.22 ELECTROGAZ acts as the technical operator of the entire power network, and exercises a "planning" and implementation function for projects at the distribution level. Planning and execution of power network investments for generation and transmission are de facto responsibilities of MINITRAPE, as representative of the Government (Conseil National de Développement) while MINITRAPE has the option of appointing an ELECTROGAZ agent to participate. This is the case even when the debt is financed and local funds generated from ELECTROGAZ' own resources. This arrangement has weakened the planning and programming process in which ELECTROGAZ, as the national power entity and network operator, normally would have a major role. Furthermore, this artificial division of responsibility has lessened coordination in network operation: the same duality in planning of power production/transmission on one hand and distribution on the other is carried over into ELECTROGAZ' internal organization, weakening operational links between the two (para. 5.25).

5.23 ELECTROGAZ' ability to function as a normal utility is also constrained by MINITRAPE and MINIFOPE control over key staffing decisions. ELECTROGAZ has 987 permanent staff of which only 42 are engineers, while 250-300 represent unskilled labor for buildings and public works. In addition, ELECTROGAZ employs some 3,000 temporary workers (equivalent to 500 salaried staff) to execute various force account works it undertakes on its own or MINITRAPE's behalf. Only 8% of ELECTROGAZ' personnel are university graduates, with an additional 13% being high school graduates. Engineers and other skilled technicians are paid almost the same low salaries as civil servants which results in a high losses to the private sector. The practice of force account construction may have been justified at a time when the private sector was inactive. However, given the very encouraging development of Rwanda's private sector and the desire of the Government to see national economic growth stimulated by these agents, there is no reason for ELECTROGAZ to continue to carry out its own works. On the contrary, management should divest itself of activities which divert its attention from its specific objectives of a commercial public utility.

5.24 ELECTROGAZ also has little control over its own financial soundness. Its investment budget is the result of projects it is instructed to undertake, while its operating budget is established in accordance with general Government guidelines and objectives, rather than the real cost of operating and maintaining its facilities. Power and water rates are approved by the Council of Ministers, based on recommendations by MINITRAPE, without a rational pricing policy linked to the economic costs of service or financial soundness of the company. For the electricity sector, rates were not adjusted from 1982-87, a period during which ELECTROGAZ received substantial subsidies from donors for equipment and from the government development budget to finance local counterpart funds for investment projects. High rates and subsidies put ELECTROGAZ in a sufficiently comfortable cash position to undertake force account construction of non-productive assests such as houses, offices, and warehouses at the consumers' expense. However, a tariff study completed by SAUR-Afrique and the French state-owned company Electricité de France (EDF) in 1987 showed that by 1988, even after operating cost-reduction measures, debt accumulated in the early 1980s would become due, necessitating an average rate increase of 15%. In January 1988, the Government chose to ignore the results of the study and lowered power rates by an average 14%, judging that this would make electricity more affordable. The lower rates, combined with a decrease in government subsidies and continued accumulation of government receivables in 1988 have instead decreased ELECTROGAZ' ability to expand service to new customers and meet its debt obligations to the Government. However, by mid 1991 electricity tariffs were increased approximately by 50% following the Rwanda franc devaluation.

5.25 As a mixed product utility, ELECTROGAZ' electricity, water, and gas operations share common administrative, financial, and support services (workshops, garage, training facilities, etc.). While this arrangement may be more economical and make the best use of scarce managerial resources, the absence of separate accounting by operation prevents the analysis of the financial viability of each operation. The same is true for commercial operations: water and electricity consumption are billed jointly, so that management of receivables is more difficult, and outstanding payments by operation cannot be derived. Transparency should be introduced into ELECTROGAZ' accounting in order that key policy decisions, especially for pricing, be based on complete information on the viability of each separate operation. ELECTROGAZ should prepare financial statements (balance sheet, operating account, sources, and utilization of funds) for each of its operations.

5.26 ELECTROGAZ' organigram as established by Presidential Decree of August 8, 1978 is given in Annex 3.6. Since this organigram was issued, however, several modifications have been made to ELECTROGAZ' internal organization including the creation of a commercial division which reports to the Director and of a computing division which reports to the accounting section of the Administrative and Financial Department (AFD). ELECTROGAZ' present internal structure could be made more effective with relatively few modifications. First, as noted in para. 5.22, above, a major change must be made to integrate operations at the distribution level (where water and electricity distribution are joined and "regionalized" according to the location of a water treatment plant and its corresponding power plant or substation) with those at the production and transmission level (the responsibility of Technical Electricity Services). Second, within the AFD there is: (a) an internal audit unit which, in order to properly execute its independent review function, should report to the Director, and (b) a computer services unit which reports to the accounting section, but should report instead to the head of the AFD to ensure that all units in the enterprise which require its services have equal access. Third, personnel services, in spite of its direct link to the Director, does not have the hierarchical status of other departments; while this deficiency may be attributable to the limited role it plays vis-à-vis MINIFOPE, its mandate should be broadened to the full scope of human resources management and the correct status accorded to it.

5.27 In recognition of the need to correct the structural and managerial weaknesses which have hindered ELECTROGAZ' effective operation as a public utility, the Government has included this enterprise among a group of wholly and partly Government-owned enterprises to be restructured. For ELECTROGAZ to operate as a commercial utility, its general and personnel statutes will need to be modified considerably. With regard to the former, ELECTROGAZ must be given the autonomy necessary to manage its day-to-day water, power, and gas operations, including a fully empowered director and board. As for its personnel statutes ELECTROGAZ should be separated from the civil service, and the company's management given full control over human resources policy (recruitment, termination, training). Concurrently, ELECTROGAZ' organic structure should be reexamined and revised in line with new responsibilities which will result from greater managerial autonomy and from the future expansion of the electricity sector as set forth in the Power Master Plan. However, because of its monopoly status, particularly for the power sector, a regulatory framework is also needed to permit the Government to monitor ELECTROGAZ' technical and managerial performance and to ensure cost-effective delivery of service in line with industry norms. The transition to a commercial utility will require careful phasing and substantial external support, either through technical assistance or twinning with a foreign utility. A CCCE/IDA-financed study completed in mid-1986 by SAUR/CEGOS/EDF (Etude institutionnelle, structurelle et de réorganisation générale) made detailed recommendations for structural and managerial reform, including a proposal for privatizing part of ELECTROGAZ' activities. This report is a good basis for initiating the process of enterprise reform and recommendations to improve ELECTROGAZ operational and financial performance which need not await a complete legal reform to have a positive impact on ELECTROGAZ overall performance.

Reliability of Domestic Supply

5.28 Generation. In spite of recent rehabilitation of hydroelectric plants, each has technical problems of varying severity. Ntaruka, whose rehabilitation is being completed, is unlikely to attain its specified power output, because of cavitation. There is also an unresolved issue concerning the protection of the turbines from water-borne debris. At the Mukungwa plant, there are instrumentation problems. Output meters are oversized by a factor of 10 so that the only indication they provide is whether or not an output is supplied. Instruments intended to record conditions at the reservoir are inoperative because a cable has not been installed to connect them to sensors at the reservoir. At Gihira, there are also some oversized instruments and high-pitched noises emitted by the alternators when excited. The noises--a dangerous occupational hazard for plant personnel--are caused by vibrations which may result in major equipment damage. As for the Gisenyi plant, the hydraulic structures require overhaul for the fourth time since 1980 because of the high sand content of the Sebeya River and the ineffective use of de-sanders introduced during the first rehabilitation which cannot be used correctly without decreasing the water throughput and hence the station power. A solution is being studied with support from German bilateral assistance, and consists of surface-hardening the turbine rotors in order to increase the intervals between overhauls. An alternative solution would be to increase the diameter of the water pipe from the reservoir to the de-sanders, so that sufficient water would be available at the turbines with the de-sanders fully operational. An analysis is needed to determine which solution is more cost effective.

5.29 It is noteworthy that the construction or recent rehabilitation of the four power stations have been supervised by different consulting engineers, yet technical deficiencies have occurred in every case. This heightens the importance of rigorous supervision by the Rwandese authorities and by the donors who finance such projects.

5.30 Transmission. In 1987, high voltage (HV) transmission is at 110 kV and 70 kV, over 349 kilometers (km), with 13 substations. MV transmission is at 30 kV, 15 kV, and 6.6 kV, over 934 km. There is ample HV capacity. Data were not readily available on the MV system, but demand growth in Kigali and Butare, evidenced by overloading of portions of their distribution networks, may have resulted in some capacity constraints at the MV level.

5.31 Rehabilitation of the HV network, including substations, is being completed, with financing from the Caisse Centrale de Coopération Economique. However, rehabilitation of the MV sections of the substations has been patchy. At Kigoma, for example, the main 30 kV circuit-breaker has broken down and has simply been removed. Automatic reclosure of 30 kV circuit-breakers downstream from Kigoma, which was to have been installed as part of a recent World Bank-financed energy project, is inoperative because the circuit-breaker motors have burned out. Inadequate protection is placing transformers at risk, and a transformer failure could black-out substantial portions of the power system. As ELECTROGAZ has no spare transformer, bringing one from Europe could leave parts of the network crippled for at least six months. As the risk of transformer failure can never be fully eliminated, ELECTROGAZ should make provisions for dealing with such a failure by purchasing spare transformers.

5.32 Distribution. There are 12 distribution centers serving a total of 13,717 connections, of which 13,355 are LV and 162 MV. Kigali is the largest of these, with 8,107 connections (8,003 LV; 104 MV). There are no comprehensive records of the condition of the distribution system. As a preliminary step to preparation of the Power Master Plan, ELECTROGAZ will prepare inventories of distribution system components and cable routes, including their capacity, loading, age, and condition. There is sufficient information available, however, to show that much of the distribution equipment is worn-out and that many of the protective devices are unreliable. Parts of the distribution system, notably in Kigali and Butare, appear to be overloaded. High priority should be given to preparing the information which will serve as the basis for a distribution rehabilitation plan. As new distribution extensions may strain an already weak area of the network, it should be undertaken in conjunction with priority renewal and strengthening of the existing network. Parallel to the Electricity Master Plan study, another study will be undertaken to rehabilitate the networks of Kigali, Butare, Nyabisindu, Ruhengeri, and Gisenyi.

Operations and Maintenance

5.33 *Operations*. Rwanda's network has been subject to high transmission and distribution losses. These losses, both technical and non technical, averaged over 20% during the period 1982-84 but declined subsequently to just under 17% in 1987. Sensitization of management and staff of ELECTROGAZ to the loss issue has resulted in: (i) better billing and collection practices, including closer supervision of metering; and (ii) interchange of some distribution transformers to achieve a better match between capacity and load. It has not been possible to break down the losses with any precision into their respective technical and non-technical components because of inadequate measuring capability. The characteristics of measuring transformers, and hence the ratios by which meter-readings have to be multiplied, have been misrecorded in some cases, while other meters are oversized and therefore cannot be read accurately. ELECTROGAZ is now calibrating its meters, a first step to better diagnose its loss problem and identify additional corrective measures.

5.34 In spite of interconnection with Zaire which would allow imports of about 40 GWh annually, Rwanda has recently taken only about half that amount of energy, preferring instead to operate its power plants above their rated annual available production (Table 5.2). This practice has steadily lowered lake levels over time. Lake Bulera, which supplies the Ntaruka plant, fell by about 1 m between 1962 and 1973 and by about 3 m between 1973 and 1987, and the level of Lake Ruhondo, which supplies the Mukungwa plant fell by 0.4 meter between 1983 and 1988. As Table 5.2 shows, both plants have generally been used at 25-30% over their guaranteed annual production and thus their respective water replenishment levels. ELECTROGAZ has proposed to restrict Ntaruka's output to allow Lake Bulera to recover by maximizing the use of Ruzizi II's power, and to utilize Ntaruka production primarily to meet peak demand. While this could be a satisfactory policy, all options for meeting base and peak demand should be studied to find the best solution in terms of lowest cost and protection of Rwanda's resources. See also Chapter VIII.

Table 5.2: COMPARISON OF GUARANTEED ANNUAL PRODUCTION WITH ACTUAL PRODUCTION 1984-87

Power Plant	Guaranteed Annual Production (GWh)	Actual Production (GWh)			
		1984	1985	1986	1987
Mukungwa	45	58.33	55.20	55.86	60.55
Ntaruka	22	29.15	27.20	23.96	28.06
Gisenyi	5.4	6.41	5.70	6.02	8.20
Gihira	10	-	-	8.80	11.53

Source: ELECTROGAZ.

5.35 Reliable data for key operational indicators, outages for example, are not readily available, nor compiled consistently and analyzed by ELECTROGAZ with the objective of improving network planning. A new control center for the entire Rwandese network was recently installed, but provision has not yet been made for incorporating the output of Ruzizi II. Management of system operations would benefit from the collection and systematic analysis of statistics and definition of system operating rules under normal and non-normal conditions. These rules would need to give special attention to the issue of hydrological resource management and tradeoffs in the use of energy from domestic sources on one hand, and from Ruzizi I and Ruzizi II on the other as noted in para. 5.34 above.

5.36 Maintenance. ELECTROGAZ is receiving externally financed assistance in support of maintenance of power stations and transmission systems. Due to the limitation on foreign exchange for power sector expenditures, availability of spare parts has at times been well below needs. At present, power stations and HV transmission lines are adequately maintained, partly because donors have financed spares as part of their rehabilitation programs. Maintenance is seriously deficient on MV and distribution installations, however, partly because of lack of spare parts. The second important element linked to proper maintenance is the allocation of an adequate number of ELECTROGAZ engineers to this task. Technical assistance now being provided will have only a limited impact if sufficient counterparts are not trained and permanently assigned to continue this work.

Investment Proposals

5.37 In the absence of results of the Power Master Plan Study, the Ministry of Public Works prepared a sectorial strategy for infrastructure in the power sector totaling US$227 million in end-1987 prices (Annex 3.7). This program responds primarily to two governmental objectives: independence from power imports, and extension of ELECTROGAZ' network to rural areas (electrification of all district seats is targeted). Total power independence will have a relatively high economic cost, and is difficult to justify because availability of imported power is guaranteed by contracts, with which Rwanda's partners have always complied. The economic viability of rural electrification should be determined on a case-by-case basis, with consideration of independent generation by small power units as an alternative to expansion of ELECTROGAZ' interconnected network.

5.38 These and other key system operation issues are expected to be examined and recommendations made through the preparation of a Master Plan for the development of the power sector, which should be completed by end-1992. The Master Plan will include detailed demand forecasts, a comprehensive inventory of ELECTROGAZ' power facilities as well as their condition and operating policies, and will present least-cost development alternatives with their priorities. Since investments undertaken before the Master Plan is prepared can lead to sub-optimal choices, a key question is what portion of the investment plan has to be initiated before the conclusions of the Master Plan become available.

5.39 Careful selection of investments is also necessary because of resource constraints. Annex 5.7 shows that yearly investments would increase more than ten-fold, from US$5.8 million in 1988 to US$63 million in 1992. Past practice has been to on-lend funds provided from external sources to ELECTROGAZ. Assuming even more favorable on-lending terms than presently available to ELECTROGAZ (3% interest per annum, lent for 15 years with 5 years grace), interest and principal payments for the electricity sector alone would be of the order of RF 483 million in 1990, RF 840 million in 1993, and RF 1,320 million in 1995. These levels should be compared to ELECTROGAZ' total debt servicing (interest and principal repayments) for water and electricity operations of RF 224.6 million in 1987. Assuming also that annual demand grows at the projected rate of 8.8% (para. 5.10), by 1993, when most loans for this program are still in their grace period, average electricity rates would need to be increased by RF 0.5/kWh per year just to meet debt service payments. An additional constraint to such a large and rapid expansion is the availability of adequate human resources to implement all the projects and subsequently operate and maintain the new facilities.

5.40 Power generation. Power station construction accounts for US$178 million, or 78% of the investment plan. It can be seen from Annex 5.8 that installation of the third 13.3 MW unit at Ruzizi II would give by far the lowest incremental cost per kW installed--US$600--compared to US$2,300-5,700 for power stations proposed to be built in Rwanda. The third unit of Ruzizi II would therefore be the most cost-effective way of providing additional power for the integrated network.

5.41 The next lowest cost source of power, US$1,900/kW installed, would also be an international power station, at Rusumo Falls. A feasibility study has been completed, but detailed engineering is not yet available making costs very tentative. Furthermore, the Rusumo Falls plant would provide a very high power output (27 MW is designated as Rwanda's share) so that, depending on demand growth, a smaller power station might be more cost-effective even if its cost per kW installed were greater. The Rusumo Falls feasibility study presents both a high and a low demand scenario, with construction during 1990-93 or 1992-95, respectively. The later construction date is in any case more probable because Rwanda and Tanzania have yet to resolve a major issue on dam height, which would affect the surface to be flooded in Rwanda.

5.42 Feasibility studies for the Rukarara (9.4 MW) and Mukungwa II (3.6 MW) power plants yielded rates of return of about 9% and 6% respectively, using diesel generation as alternative. However, installation of a third unit at Ruzizi II, not diesel generation, appears to be the next best alternative, to which these stations should be compared. Furthermore, serious hydrological and geological questions have yet to be addressed at both sites, before costs can be considered firm. Answers to these questions should be obtained and the viability of the projects reassessed before the Government commits itself to their implementation.

5.43 A pre-feasibility study of the Keya plant (2.0 MW) was also completed in early 1988. While this plant would make a very small contribution to the interconnected network in terms of additional power, it could alleviate the siltation problems of the Gisenyi plant. Technical and cost data should be refined by undertaking a feasibility study as soon as possible.

5.44 Feasibility studies will begin in 1991 for the remaining stations (Akanyaru, Nyabarongo, and Rusumo-Rugezi) in order to provide technical data and reliable costs for analysis under the Power Master Plan study. Hydrological and geological data acquisition should be initiated at all promising sites so that an informed choice can be made. However, in view of the investigative or preparatory work still needed, start-up of major investments in 1990 seems very optimistic.

5.45 In conclusion, installation of the third unit at Ruzizi II is undeniably the most cost-effective new source of supply for Rwanda. As the demand projections of Annex 3.3 have shown, it is unlikely that any new generation capacity will be needed before 1995 if Rwanda takes advantage of the surplus power in the regional interconnected network. Should the detailed demand projections of the Power Master Plan confirm the need for an additional plant in 1996, completion of the Master Plan in 1992 will allow sufficient time to make a decision and to carry out the needed investment.

5.46 A generation option not included in the proposed investment plan, but which should be examined by the Power Master Plan study is that of a gas-fired plant supplied with the methane gas of Lake Kivu. Two aspects of gas supply are worth studying: base load supply and reserve supply for security purposes. With regard to base load supply from a gas-fired plant, comparison should be made with domestic and regional supply options to determine the least cost choice for system expansion. As for reserve supply, a gas-fired plant with ready availability in case of prolonged disruption of imports could be an alternative to increasing domestic base load production to reduce dependence on imports in the interest of national security. A contingency plant could allow Rwanda to benefit from continued or even increased imports of relatively low cost power from the region. While Rwanda's neighbors are likely to remain willing and reliable suppliers, the broad strategic issue of Rwanda's ability to meet the power needs of key economic sectors from internal sources of supply under various disruption scenarios should be studied. A key decision for the Government of Rwanda is what cost it is prepared to incur to achieve certain increases in energy self-sufficiency.

5.47 Transmission and distribution. Transmission and distribution investments amount to US$49 million, or 22% of the total interim plan. Studies are available for only two projects. One is the electrification of six urban centers, for which an African Development Bank loan of US$9 million has been made. The other, financed by the Kredietanstalt für Wiederaufbau (KFW) at a cost of US$2.8 million, consists of the extension and some rehabilitation of three MV line sections, with extension of LV distribution; a fourth line may also be rehabilitated or replaced (para. 5.48). Studies are not available for other transmission and distribution investments which relate to system extension rather than rehabilitation. The biggest distribution investment is for the extension of electrification to Kigali's outer districts, although overhaul and capacity increases of Kigali's existing distribution system appear to have greater priority. The interim investment program could be improved by giving more emphasis to distribution rehabilitation and expansion given that donor-financed projects have neglected this important part of the network. However, all distribution expansion should emphasize lowering the capital costs of this part of the network and making new connections more affordable by using more overhead cables (in 1987, 67% of distribution cables were underground), matching the type of household connection to the clients' consumption needs (i.e., a wider use of monophase connections) and design of complementary commercial policies which encourage new consumers to connect.

5.48 High priority is accorded to rural electrification which has as its basic objective to establish several rural centers that will serve as development poles, thereby reducing regional disequilibrium and stabilizing population movements. It is intended to equip these centers with adequate infrastructure and administrative institutions and provide basic services; electricity is thought to be one of the necessary components to achieve the desired development objective.

5.49 Accepting the desirability of establishing regional development poles, it should be noted that by itself the provision of electricity is not sufficient to convert a rural center into a development pole. Some areas which are already electrified are not yet development poles, and will not evolve into them without new actions and complementary investments. At the present time, Rwanda does not have a comprehensive and coherent strategy of regional development. Also, some alternatives ways to supply electric power to rural centers, such as the installation of small diesel units, the utilization of local minihydro power plants or, for small power needs, the use of photo-voltaic systems, may be less costly and more advantageous in the initial years than interconnection with the national electric grid. Rural electrification projects must therefore weigh different options to determine which is least-cost and undergo the same rigorous economic analysis as any other development project to determine their viability.

5.50 At the present time, there is one rural electrification program in execution and another one in the study phase. The program in execution is the electricity component of a project to supply water and electricity to the principal localities of the sub-prefectures. The prefeasibility studies were finished in 1986. A credit of DM 11.4 million (approximately US$7.2 million) was awarded in October 1987 by KFW to execute the project. Local counterpart requirements are estimated at DM 2.8 million (approximately US$1.8 million). The localities chosen to be electrified are Kabaya, Kanazi, Kinihira, Murambi, and Ruhango.

5.51 The socio-economic evaluation for the project to supply water and electricity to the principal localities of the sub-prefectures was done on the basis of a point system. Different economic, demographic, technical, financial, and other factors were assigned points and weighted in a somewhat arbitrary way to find an overall index for each project. The consultants recommended the execution of the projects with higher values of the calculated index. No economic rates of return or net present values, accepted tests of project viability, were calculated and therefore there is no way to know which individual project is economically justified, or which among them is the highest priority for the country. Both rate of return and present value calculations could have been done with the information presented in the report.

5.52 The rural electrification project presently under study is financed by the Caisse Centrale de Coopération Economique, of France, and includes about 310 km of 30 kV lines connecting the following centers: Nyakinama to Muhororo, Byumba to Nyagatare, Butamwa to Kiyumba, Save to Akanyaru, Rulindo to Musasa, Gatagara to Masango, and Mukungwa to Janja. In a first phase, a detailed economic study will be undertaken. In this study, for each important potential user of electricity, the consultant will identify users' present and future installation of electrical equipment as well as power to be subscribed and demand for energy. Surveys will also be done to estimate demand of commercial and residential users and artisans. A special analysis is also intended for rural centers that produce electricity using diesel generators. While the Terms of Reference indicate that the consultant must classify the lines in terms of economic advantage, there is no indication that the internal rate of return or the net present values will be calculated.

5.53 An examination of several completed projects, including the 30 kV line between Ntaruka and Cyanika and the 15 kV line between Gifurwe and Gakenke financed by the World Bank, shows that most feasibility studies have overestimated the demand for electric energy in rural centers. Consumers have not been connected to the electric system in the projected numbers and unitary consumption has been much lower than expected. Part of the problem is explained by the fact that the demand projections have not taken into account either connection charges which, as discussed in para. 5.6, are quite high or existing and future tariffs. The overestimation of demand has led to investments benefitting few people; in retrospect therefore, these projects are not likely to be economically viable or at best were premature.

5.54 The analysis of rural electrification projects must be improved to assure correct investment decisions including the identification of the rural centers where investment in electrification is the most advantageous to the economy as a whole. The methodology to be applied should consider the following:

(a) Demand projections must take into account connection and tariff charges and must be based on the experience of recently executed similar projects with respect to the evolution of unit consumption and the rate of connection of potential users;

(b) An economic comparison between the alternatives of extending transmission lines from the national power grid and developing local sources of electric energy (diesel generators, available minihydro sites, photovoltaic development, etc.) must be undertaken for each project;

(c) Economic rates of return must calculate as benefits the value of electrical energy sold to consumers as well as the possibilities of substituting electric energy for other existing sources of energy. In many cases tariff revenues have been the sole benefits considered which underestimates the real value of a project. Annex 3.9 presents a brief description of the methodology that should be used for this purpose. This methodology does not require more information than what is presently collected;

(d) Potential projects must be ranked in terms of the economic net present value using an acceptable opportunity cost of capital.

Tariffs

5.55 Electricity tariffs in effect at the beginning of 1991 were approved by a decree of the Minister of Finance and Economics on January 7, 1988. This decree replaced tariffs that had existed since December 29, 1981 and reduced, among others, nominal charges per kWh by 35% for LV users and between 9% and 11% for MV users. Since in the period 1982-86 inflation is estimated to have been 15%, there has been a substantial deterioration in the real level of electricity rates.

5.56 For LV users there is only a constant energy charge of RF 8.5/kWh (approximately US$0.11/kWh), while MV users have charges for energy and for peak demand which vary in accordance with the capacity of their installed equipment. For a capacity below 100 kW the tariffs are RF 8.0/kWh and RF 486/kW/month of registered peak demand, while for capacities above 100 kW the charges are RF 5.0/kWh and RF 774/kW/month of registered peak demand. Since the average annual number of hours of utilization has been 2,985 for capacities below 100 kW and 3,760 above 100 kW, average charges per kWh for MV users are RF 10.0 and RF 7.5 respectively (approximately US$0.13 and US$0.10). Following the 1990 devaluation, electricity tariffs were increased by 50% in July 1991.

5.57 The LRMC of electric power in Rwanda is estimated 6/ at approximately US$0.17/kWh at MV and US$0.20/kWh at LV distribution (Annex 3.10). Therefore, actual rates for LV users (mainly residential consumers) are about 43% below their marginal cost, while MV tariffs are between 22% and 41% below the LRMC of electricity delivered at that level. A table comparing present rates with their LRMC is given below. Present residential users of electricity, which represent a low proportion of total population and are likely to be in the higher per capita income brackets, are receiving substantial subsidies from the Government through the existing tariff structure.

Table 5.3: ACTUAL POWER RATES VS. LRMC
(RF/kWh)

	As of 01/01/88	LRMC
Production	-	6.8
Transmission	-	7.3
Distribution		
MV	10.0/7.5	12.8
LV	8.5	15.0

Source: ELECTROGAZ and Mission estimates.

5.58 In 1985 there were 1,052 users who consumed less than 45 kWh per month and 1,490 users who consumed more than 500 kWh/month. The consumption of the first group represented 0.8% of total LV consumption, while that of the second group was 62.4%. These figures indicate that this last group receives the largest share of the Government's subsidy. It is likely that the latter group is the most able to bear the cost of electricity, while the former group is characteristic of consumers who could be eligible for a "social tariff." The pattern of declining consumption per unit at the LV level as the number of new LV consumers grows indicates that network expansion is progressively reaching lower income groups. This trend can only continue if access to electricity is made easier for these groups. Lower connection charges coupled with a social tariff should be adopted. For equity reasons, a social tariff below the cost of LV power would be acceptable with the cost of the subsidy borne by another consumer group or, if that is not possible, by the Government in a transparent fashion. The existing subsidy to large consumers has no such justification and should be eliminated.

5.59 The present policy of differentiated tariffs for the two categories of MV users based on the capacity of the installed equipment is also without justification. First, the cost of delivering power is the same to both consumer groups so that different rates could not be rationalized on this basis. Second, a differentiated tariff would be used when costs of delivering power are the same, if the desired result were to obtain different consumption behaviors. There appears to be no reason to encourage greater consumption by clients with larger installed capacity, and in fact, there is a danger of encouraging investment in oversized equipment to benefit from the cheaper electricity costs.

6/ *Before the devaluation of the Rwanda Franc in 1990.*

5.60 As noted in para. 5.3, the recent large growth in peak demand is in part due to growth in residential consumption. In order to avoid investment in new plant capacity which would have the impact of raising power rates to all consumers, it would be preferable to try to reduce or defer consumption during peak hours through the price structure. Time of day tariffs should therefore be examined to see whether they could encourage more efficient consumption patterns.

5.61 ELECTROGAZ engaged SAUR-Afrique and EDF as consultants for a tariff study which was completed 1987. Recommendations of this study were not taken into account by the Government in the latest tariff decree. A comparison of the previous and present key tariffs, together with the tariff recommendations made by the consultant, in constant end-1986 RF, are presented in Table 5.4 below:

Table 5.4: ELECTRICITY TARIFFS

		1981-1987	As of 1/1/88	Consultant Proposal
LV	Energy: RF/kWh	13.0	8.5	13.0
MV	a.- Below 100 kW (2,600 hours of utilization for consultant)			
	Peak: RF/kW/month	540	486	150
	Energy: RF/kWh	9.0	8.0	9.0
	b.- Above 100 kW (2,600 hours of utilization for consultant)			
	Peak: RF/kW/month	860	774	730
	Energy: RF/kWh	5.5	5.0	6.3

Source: ELECTROGAZ.

5.62 It should be noted that the SAUR/EDF study does not determine long-run marginal (or average incremental) cost prices based on a rigorously established long-term least-cost Master Plan. The Power Master Plan study will include such calculations, and ELECTROGAZ' tariffs will be re-examined on this basis. The results of the SAUR/EDF study do nonetheless show that the present rate levels are too low both in economic terms and for ELECTROGAZ to meet sound financial objectives, particularly with respect to debt obligations. The separation of MV consumers by installed capacity of their equipment has been eliminated; MV consumers are now distinguished by the average annual number of hours of utilization and differentiation between HV consumer categories is based on a fixed energy charge related to peak; higher prices are charged the greater the contribution to the peak. This is an appropriate pricing structure for Rwanda where peak demand has been rising more rapidly than average demand (the load factor has fallen from 66.5% in 1984 to 58.5% in 1987). In the absence of the marginal-cost tariff study of the Master Plan, tariff adjustments should be made in line with the recommendations of the SAUR/EDF study.

Recommendations

5.63 The recommendations of the mission with regard to highest priority Government actions for the electricity sector are as follows:

(a) Demand:

(i) In the absence of the results of the Master Plan study, new investments should be limited to expanding low tension connections and industrial connections in areas where service is already available. ELECTROGAZ should launch a promotion campaign to this effect.

(ii) Distribution in areas not already served and in rural areas should be expanded based on low-cost technical standards; donors should be asked to fund one or more pilot low-cost distribution schemes to test the appropriateness and viability of such an approach.

(iii) A better connection policy should be adopted which spreads the initial cost of a connection borne by the consumer over time.

(b) Supply:

(i) Rigorous supervision of rehabilitation and construction projects should be given more attention by MINITRAPE, ELECTROGAZ, and donors to ensure that the highest quality product is obtained.

(ii) Appropriate measures should be taken, including the purchase of a spare transformer and circuit breakers to be installed at Kigoma, to eliminate the risk of a major network blackout due to equipment failure.

(iii) The distribution network should be inventoried in all key population centers to serve as the basis for the distribution rehabilitation plan which should result from the Power Master Plan Study.

(c) Network Operation:

(i) Network operating rules should be defined for normal and non-normal conditions which are based on the systematic collection and analysis of operating statistics.

(ii) Urgent attention should be given to correcting the problem of decrease in lake levels and ensure that the newly defined network operating rules adequately address management of hydrological resources.

(iii) The power network loss study should be completed and the measures which would progressively reduce losses to a satisfactory level should subsequently be implemented.

(iv) A study on the capacity constraints at the MV transmission level should be carried out.

(d) Institutional:

(i) ELECTROGAZ should be restructured to perform better as an autonomous public utility which can renew, expand, operate and maintain its installations and achieve commercial and financial performance objectives in accordance with commonly accepted utility practice.

(ii) Transparency should be introduced into ELECTROGAZ' three utility operations by preparing separate financial and commercial data.

(e) Planning:

(i) A sound methodology to be applied in the evaluation of all rural electrification projects should be adopted.

(ii) Commitment to major new investment projects, particularly construction of new power plants, should be deferred until preliminary results of the Power Master Plan indicate the least cost option and its optimal timing based on detailed demand projections.

(iii) The Power Master Plan study should also consider a generation option based on methane gas from Lake Kivu.

(f) Pricing:

(i) The level and structure of existing tariffs should be modified in line with marginal cost pricing principles in order to reflect the cost of service and eliminate disguised subsidies electricity consumers have received from the Government.

(ii) Negative effects of LV rate increases on low-income consumers should be reduced by introducing a social tariff linked to a consumption level appropriate to this income group.

5.64 Other actions considered important, but of lesser priority are the following:

(a) Demand:

(i) Demand studies for new network expansion should take into account existing or future connection charges and tariffs.

(ii) Conversion of existing industrial boilers to electricity should not be promoted if subsidies must be given for the purchase of new equipment and/or present industrial rates must be reduced.

(b) Institutional:

(i) ELECTROGAZ' personnel unit should be provided with the expertise and logistical means needed to prepare a human resources plan aimed at: (i) initially providing the restructured enterprise with adequate competent staff; and (ii) in a second phase, developing and expanding staff in line with the outcome of the Power Master Plan.

(ii) The present practice of force account construction should be reconsidered with a view to divesting from ELECTROGAZ part of such activities.

(c) Planning:

(i) Hydrological and geological data should be established for all potential hydro sites.

(ii) A rural electrification policy should be developed as part of a comprehensive regional development strategy.

(d) Pricing:

(i) The present distinction between the two categories of MV users with installed capacities below or above 100 kW should be eliminated.

(ii) The appropriateness of tariffs which favor utilization of electricity outside peak hours should be examined.

VI. METHANE GAS

Background and History

6.1. Lake Kivu is a potential energy and feedstock resource of a type not known elsewhere in the world. Methane is dissolved in the deep waters of the Lake with reserves estimated at 60 billion Nm^3, of which some 50 billion Nm^3 are considered recoverable. Observations suggest that the resource is being renewed naturally by 250 million Nm^3 annually (see Annex 4.1). Given the magnitude of this resource--recoverable reserves without renewal represent in energy equivalent some 500 years of the present consumption of petroleum products in Rwanda--and considering the dependence of Rwanda on imported high cost petroleum fuels and petrochemicals such as fertilizers, careful consideration of production and potential uses of this resource as fuel and feedstock is amply justified.

6.2. A pilot plant built in 1963 at Cap Rubona on the Rwandan shore of the Lake and operated by ELECTROGAZ has demonstrated the technical feasibility of gas development, albeit on a small commercial scale. To date, some 20 million Nm^3 of methane gas has been extracted. Nearly all of the gas has been used as a boiler fuel in the nearby BRALIRWA brewery, with very small quantities compressed into CNG for pilot use in converted gasoline-fueled vehicles. To fully meet the fuel requirements of the brewery, Rwanda has been considering a quadrupling of the net production capacity of the onshore Cap Rubona pilot plant. This investment, for which the equivalent of US$13 million in Belgian financing is foreseen, would have an annual capacity of 7.2 million Nm^3. In addition to meeting the brewery's needs, the possibility is being considered to supply a moderate quantity of surplus gas to a gas compression unit for vehicle propulsion; consideration should also be given to pursue demonstration of desirable gas uses in power generation.

6.3. Lake Kivu straddles the border of Rwanda and Zaire. Both countries agreed in Bukavu, in 1975, that the gas resource was their joint property and would be developed by a bipartite, equally owned entity, the Société Internationale d'Exploitation, de Transport et de Commercialisation du Gaz Méthane du Lac Kivu (SOCIGAZ). The two governments entrusted a Joint Technical Commission to draft its statutes and to commission studies on the Lake's behavior under continuing large-scale gas extraction and on the feasibility, costs, and economics of various schemes of gas production and utilization in both Rwanda and Zaire. The supply/demand and technical rationales underlying early studies, were that:

(a) gas development projects: (i) could be large given the magnitude of the resource and to realize the benefits from economies of scale, and (ii) ought to be composed of various end-use components in order to enable the countries to take full advantage of domestic gas as a fuel and a feedstock; and

(b) owing to the successful experience of the Cap Rubona pilot operation, no changes in concept and technology would be required but only an extrapolation in size and distance. Production facilities were initially designed onshore; individual gas demands could be of the same order of magnitude or larger than that of the brewery, and several transport modes of transport to markets have been considered.

6.4. In both Rwanda and Zaire, multi-component "Grands Projets" (see para. 6.9) were defined based on potential gas users with an annual consumption in the range of 25 to 30 million Nm^3 of gas. The risks of destabilization and exhaustion of the resource at such a level of production were analyzed extensively and various combinations of end-uses, pipeline routes, and production sites, under different scenarios for growth of demand and for increases in the price of oil-based fuels and derivatives, were evaluated. The outcome of the studies gave a mixed picture of the prospects for gas development:

(a) with regard to environmental impact, it was concluded that there were no risks in sustained gas production at the 25-30 million Nm^3/year scale if reasonably simple, and cost-affordable measures were taken and maintained (see Annex 4.1);

(b) with regard to the economic viability of the approach, even with phased implementation, all the "Grand Projets" could not demonstrate an acceptable return except by using market demand and pricing assumptions which cannot be considered realistic; as a result, only the supply of gas to the existing CIMERWA cement plant at MASHYUZA, 20 km from the Lake's edge in Rwandan territory, (estimated consumption of 24 million Nm^3/year) was considered to be economic, at the margin.

6.5. Although it was the most attractive option for gas development, the project to supply the MASHYUZA cement plant still had a marginal rate of return due to its relatively high capital investment costs (US$25 million). Its technological interest as the first step of a systematic development of the Lake was also limited. The production and transport options proposed relied heavily on the onshore technologies used at Cap Rubona, without adequately updating them or adapting them to a potentially broader and growing market for gas.

6.6. Aware that financiers were not likely to be forthcoming to implement the "Grands Projets" approach, the Joint Technical Commission decided, early in 1988, to explore the possibility of reducing gas production and transport costs by improving the processes for extraction and methane enrichment, and through gas conditioning into CNG and LNG for transport to end-users by barge and road. Studies which were concluded in late 1988 included lab tests and site experimentation on gas extraction at more than atmospheric pressure, gas production module optimization and analysis of gas distribution options including production and distribution of CNG and LNG. While these studies were primarily targeted at reducing the cost of gas supplied to the one potentially viable consumer, the MASHYUZA cement plant, and incidentally to the CIMENKI cement plant located at Katana in Zaire, their general conclusions are encouraging for two reasons:

(a) first, the use of a combined CNG barging/gas pipeline mode of transport reduced the cost of gas supplied to the MASHYUZA cement plant by some 20%, implying that with some additional economies the project might well have a financial return attractive to even private investors;

(b) second, if gas substitution for fuel oil to a large, distant consumer is economic, the same may be true for gas substitution for fuels of higher value: diesel/gasoline/woodfuels, for end-uses closer to the Lake, despite dispersed smaller individual demands. This applies to the shores and surroundings of the Lake in Rwanda and Eastern Zaire. Furthermore, if gas transported to MASHYUZA is economic by a sufficiently large margin, it might be cost-competitive further south, implying that gas supply to Burundi, at least to the northern parts, might also be an economic option.

6.7. Even with the results of the latest studies, however, important questions remain unanswered and a project which is both economically and financially viable remains to be identified. First, further reductions in costs at the extraction and/or transport stages will be necessary to ensure the economic viability of gas development. Second, the size and location of the potential markets for various forms of gas at different price levels is not known. Past studies have not analyzed in detail the offshore production option, nor have they reviewed the possibility of supply and distribution to dispersed medium and small fuel consumers. Offshore production and compression facilities could realize investment cost savings and reduce transport costs by optimizing location of the production site in relation to the larger gas market. Until these options are reviewed and analyzed, the technological and transport solutions identified to date cannot be considered least-cost.

<u>End-Uses and Markets</u>

6.8. <u>The "Grands Projets" Approach</u>. According to the conventional wisdom of the petroleum industry, the development of a gas resource and the creation of a pipeline infrastructure to supply its markets require a "massive" application market in order to achieve an acceptable project return. In general, bulk uses of gas are in power and industrial plants where gas displaces fuel oil; in new industries as a feedstock for processing into derivatives; or in export projects producing LNG or ethanol.

6.9. For the methane gas of Lake Kivu, the conclusions of the inventory of such conventional bulk uses, under the "Grands Projets" approach may be summarized as follows:

(a) <u>exports</u> (in this case targeting international rather than regional markets) are not a realistic alternative owing to the high transport costs from landlocked Lake Kivu;

(b) <u>power generation</u> was from the inception of the studies never envisaged as a gas application, except in isolated rural areas, and was therefore never the object of a detailed evaluation. This particular omission needs to be rectified since gas-fired power plants, particularly for stand-by, may well represent an interesting opportunity to reduce the cost of power supply in Rwanda;

(c) <u>industrial plants</u>, with individual fuel consumption, actual or projected, large enough to constitute a desirable "massive" gas demand are scarce in the region and, in Rwanda were found to be represented only by (a) the BRALIRWA brewery, fed by the Cap Rubona pilot plant and (b) the CIMERWA cement plant at MASHYUZA. Gas production and transport costs are in the former case very small, but in the latter case significant, making gas pipelined to the MASHYUZA plant only marginally economic (based on the concept and technologies envisaged under the "Grands Projets");

(d) gas processing into derivatives was considered for urea primarily in Rwanda, for methanol primarily in Zaire, and for synthetic gasoline and diesel oil in several countries of the region;

(i) urea and methanol processing require plants of a considerable size to benefit from economies of scale. To be financially and economically viable, such projects need markets that can rapidly match production capacity. Furthermore, the cost of the feedstock gas must be low enough to make the locally-produced derivatives cost-competitive with the imports they would displace. Only the production of urea in Rwanda at a cost estimated at US$330 per ton (1986 prices) would be marginally economic in a plant with a capacity of 20,000 tons/year, considered to be the minimum economic capacity. The demand for urea in the region is not, however, expected to reach that level before the year 2000. Lake Kivu's gas may eventually, in the more distant future, be used in the production of urea and methanol, but the prospects are highly uncertain in terms of timing, volume, and economics.

(ii) synfuels would be much-needed substitutes for imported motor fuels, but there is a difference in the order of magnitude between the minimum economic production scale of the industry and the size of regional demand, even taking a longer-term perspective. Lake Kivu's gas would therefore appear to have neither an immediate nor a prospective market in the production of synfuels.

In brief, the studies of the "Grands Projets" were unable to identify in Rwanda or Zaire, any economic bulk end-uses of the gas as a fuel or as a feedstock in the near or medium term.

6.10. A Local Market-specific Approach. While natural gas in general has its most typical applications in bulk end-uses, methane gas is also commonly used in urban households, and has made remarkable inroads in the vehicular fuel market, mostly as CNG. This type of gas development differs from the conventional one pursued by the "Grands Projets" approach, in that the markets are made up of a collection of medium and even small individual gas demands from both stationary and vehicular consumers who, being dispersed, receive CNG cylinders or LNG bottles rather than, but not at the exclusion of, pipeline gas.

6.11. The demand for petroleum products and woodfuels in Rwanda is comprised predominantly of medium and small consumers who, theoretically at least, would represent the largest potential market for Lake Kivu gas. Of the total 102,000 tons of petroleum products imported by Rwanda in 1987, 9,000 tons were in the form of kerosene and LPG used by small commercial enterprises, institutions, and households, 27,000 tons were diesel oil used in heavy vehicles and in isolated power generators, and

37,000 tons were gasoline used in cars and other light vehicles. Furthermore, the same year, the equivalent of 1 million TOE in the form of fuelwood and charcoal were burned, mainly in households but also in small agro- and other industries and by institutional consumers. To illustrate, if methane gas substituted for only 5% of these fuels, the demand for gas would be more than four times that of the MASHYUZA cement plant based on operation at existing full capacity of 75,000 t/year (cost and affordability are, admittedly, highly limiting factors in such a comparison).

6.12. Another option, which can potentially constitute a large scale utilization, is the use of gas for electricity production where the power plant is part of the grid and used for base loads. An additional option with particular interest for Rwanda would be the use of a gas-fired plant for reserve supply, i.e., a contingency plant for security purposes. A stand-by plant could be a lower cost alternative to increasing domestic base load production as a means of reducing overdependence on imports. The relevance of such alternatives in the case of Rwanda is also raised in the chapter on electric power. 7/ In several gas-rich developing countries, e.g., Nigeria and Thailand, the use of gas for power production is not only the lowest-cost alternative for producing electricity, but often also a pre-condition for justifying the expense of building a gas delivery system that can be utilized to supply other users at reasonable costs. 8/

6.13. As noted in para. 6.7 above, the most recent studies on CNG/LNG distribution and optimization of gas extraction modules could have been improved by also examining and analyzing the market comprised of medium to small gas consumers rather than limiting their objectives to cost reduction in the supply of regional cement plants. Their outcome nonetheless gives an indication, though not evidence, of the cost competitiveness of gas in end-uses other than cement production.

6.14. Of highest priority, therefore, is a complete study of the market for gas which reflects the potential demand of small- and medium-sized potential consumers primarily in the vicinities of the Lake itself, based on realistic assumptions as to supply costs, cost of alternative fuels, and affordability. Until such a study is carried out, one cannot assume the existence of a gas demand that, together with the MASHYUZA cement plant (and possibly gas-fired electric power generation), would justify the further development of the gas in Lake Kivu.

Technologies

6.15. The uniqueness of the Lake Kivu gas resource and therefore the lack of development experience elsewhere requires that particular attention be given to the choice of appropriate technologies for gas extraction, methane enrichment, and supply to the markets. Such technologies exist, but the uncertainties as to their practicability and performance under Lake Kivu specific circumstances must be addressed and resolved through actual experience with the operation of small scale demonstration units before investing more heavily in larger scale commercial plants. The choice of appropriate technologies

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7/ *In the study of the "Grands Projets" gas was considered only for use in generating units not connected to the national grid.*

8/ *Gunter Schramm: "The Changing World of Natural Gas Utilization"; Natural Resource Journal, April 1984.*

is, furthermore, the key to the reduction of the cost of gas delivered to consumers and thus its competitiveness in end-uses. As indicated earlier (para. 6.7) improved technologies (together with minimum market size) appear to be a prerequisite for economic and financial viability of further Lake Kivu's gas development altogether. The less capital intensive and more efficient the technologies, the greater the possibility for more diverse end-uses and the larger the potential demand for the gas.

6.16. In the search for appropriate technologies, quite logically, the initial direction taken by the studies of the "Grands Projets" approach was to draw on the experience gained from the Cap Rubona pilot plant. Although the production and supply of gas at Cap Rubona to the brewery have been quite successful and appear to be profitable 9/, the technical and market conditions of Cap Rubona are not found elsewhere around the Lake with respect to a (onshore) production site and the distance between the site and gas consumers (see Annex 4.2).

6.17. The failure of the "Grands Projets" to achieve acceptable returns led the Mixed Technical Commission to explore possible reductions in supply costs through a more efficient production process and a more appropriate transport mode. The studies which were undertaken in 1988 made significant inroads into key questions of extraction method and transport costs. The study on optimal extraction methods examined several alternatives for separating the gas from the lake water and enriching it (removing the carbon dioxide) to obtain a combustible gas of 75-85% methane. The solution regarded as optimal is one using a semi-offshore platform which employs three washing cycles in a vertical column configuration to arrive at an 80% methane purity. The investment cost of this solution and its cost price are the lowest of five alternatives, estimated in 1988 prices at US$21.3 million and US$126/1,000 Nm^3 respectively. As certain parts of the facilities are located onshore, investment costs increase the further the platform is located from the shore. The distance from the shore used in evaluating the optimal solution is 840 meters, but it is not certain that the gas is extractable on a large scale anywhere other than Cap Rubona at that proximity to the shore. The second lowest cost solution is based on an offshore technology with two pressurized washing cycles using a pump to return degassed water. The investment cost of this option is estimated at US$25.2 million and its cost-price at US$136.7/1,000 Nm^3. The second solution has the major advantages of flexibility in placement and displacement of its platform to different lake sites, optional incorporation of compression equipment on the same platform and the closest relationship between decreases in scale and reduction in costs (the latter is very important since the scale of operation chosen for the analysis is quite ambitious). Given the relatively small difference in costs between the two solutions and the highly theoretical element of this study, its results should not be considered conclusive or adequate to proceed with detailed engineering for the solution identified as "optimal". Fully offshore facilities incorporating compression or liquefaction facilities merit further analysis and small scale testing before a particular technology is adopted.

6.18. The gas distribution study reviewed various options for supplying compressed methane gas to two large consumers, the cement plants at MASHYUZA and Katana. The results of the studies

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9/ *The brewery pays a price for the gas to ELECTROGAZ equal to 90% of the cost of fuel oil saved. Since ELECTROGAZ does not prepare separate accounts for its gas operations and does not bear any debt related to the Cap Rubona installation accounts do not permit the determination of the profitability of the gas operation to the utility.*

show that a joint solution for supplying the two plants would not be optimal: Katana's lowest cost supply would be from an onshore extraction/compression site using transport by pipeline, while MASHYUZA is a candidate for barge supply from an onshore or offshore location with land transport assured either by truck or pipeline dependent on whether other markets are identified in Bujumbura or Kigali. The study, while it provides useful unit costs, still does not provide all information needed to define one or several gas development projects. The assumption of a 50,000 t/year production level for the Katana cement plant ignores the plant's present mismatch to the local market and low probability of attracting investors interested in financing its reconfiguration; a project to supply the Katana plant is therefore not likely to be viable for some time to come. Even the choice of production capacity for the MASHYUZA cement plant, assumed to be 85,000 t/year will require an expansion of the present plant capacity (50,000 t), a project for which financing has not yet been acquired. The choices and, most importantly, the economic viability of the extraction site and mode of transport to supply the best identified candidate, the MASHYUZA plant, are thus very highly dependent on a complementary market for other uses of compressed gas.

Costs

6.19. The cost figures available from the studies completed to date are the basis for the conclusions drawn so far regarding the profitability--or lack of such--of the different gas-uses as a fuel or as a feedstock. The technologies for gas extraction and methane enrichment are, however, not yet fully developed and may still be improved. As noted above, the option of gas production facilities located offshore has not been thoroughly analyzed, and use of CNG/LNG, as a means of distributing gas to dispersed markets other than the MASHYUZA cement plant, has not been evaluated and costed. As a result, the cost figures available from the studies of the different solutions and end-uses are incomplete or represent only partially valid options with respect to technologies and end-uses. The main findings are summarized below.

6.20. Costs of feedstock gas at the plant entry gate must be able to compete with imported feedstock at international prices, to which transportation costs are added. Based, inter alia, on varying assumptions as to the capacity of the gas production plant, the resulting cost of Lake Kivu's methane gas is high (see para. 6.23). Furthermore, the costs of processing the gas into derivatives is also likely to be high due to problems of meeting minimum plant size requirements for efficient scale of operations (see para. 6.09).

6.21. Gas used as a substitute fuel must compete with the fuels it potentially can replace in the actual Rwandan setting. Such fuels would be imported petroleum products, and local wood and charcoal. Gas is more likely to replace the former than the two latter in the short run. The costs of oil-based fuels are compared with the costs of gas in Table 6.1. The cost of imported fuels are shown CIF-Kigali, i.e., FOB-source plus transportation costs, but excluding import duties and taxes.

6.22. For the future user of the gas, however, the cost of equipment conversion must also be incorporated in the calculations. Conversion costs are end-use and not country specific, varying widely from US$100 or less (e.g., for a furnace, the new burner and piping) to US$1,000 or more (e.g., for a vehicle engine conversion, CNG cylinders, piping, and fittings). For the sake of cost comparison between fuels, capital costs for conversion are translated, assuming a certain gas consumption, into a resulting "conversion margin" per gas unit, expressed in US$/mmBTU in Table 6.1. In order for Lake Kivu gas to be an attractive substitute fuel, it would have to be delivered to end-users at a cost lower than that of fuels currently used by at least the conversion margin, i.e., the sum of gas production and transport costs should not be greater than the figures in the last line of Table 6.1.

Table 6.1: COSTS OF PETROLEUM FUELS AND GAS

US$/mmBTU Applications	Burners: Industry	Burners: Commerce	Burners: Household	Engines: Generating sets/- Fleet vehicles	Engines: Cars
Fuel displaced	Fuel oil	LPG	Kerosene	Diesel oil	Gasoline
FOB source	3.4	8.8	7.5	5.7	6.5
Transport cost	5.5	16.0	6.4	5.4	6.4
CIF-Kigali (rounded)	9.0	25.0	14.0	11.0	13.0
Conversion margin	(0.5)	(1.0)	(1.0)	(1.5)	(5.0)
Upper limit of CNG cost (Production and Transport) for different end-uses	8.5	24.0	13.0	9.5	8.0

Source: Fuel costs: The petroleum section of the present report. Gas conversion costs: Average industry figures and mission estimates.

6.23. Production costs of gas depend on the capacity of the plant and on the cost of electricity from the local grid (in case the plant does not produce its own energy from the extracted gas). Annual production of 12.5 and 25 million Nm^3 of gas with an 80% methane content were chosen as examples for the study of the "Grands Projets". Production costs for Lake Kivu gas were calculated to lie in the range from SDR 81 to SDR 160 per thousand Nm^3, or US$3 to US$6/mmBTU (million British Thermal Units). 10/ Compared to gas industry standard costs of US$1 to US$2/mmBTU, these figures are high and prompted subsequent studies to investigate alternative and more efficient gas extraction/methane enrichment technologies.

6.24. The 1988 study on gas production module optimization was successful in identifying technical solutions to reduce production costs. For gas extraction at higher than atmospheric pressure, production costs are, as a result of this study, projected to be below US$4 per mmBTU, i.e., below the mid-range of costs given above. However, as noted in para. 6.17 above this study was not exhaustive in its examination of technical options and omitted thorough analysis of the offshore option; the application of other technologies associated with offshore extraction, such as mixing of waters from various depths (Annex 4.2) could realize further cost reductions. Finally, the location of production

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10/ *Cost and other figures are from various sources and dates, and they were expressed in different energy units and in several currencies (SDR, US$, BF, and RF), the exchange rates of which have varied in the interval. Conversions and adjustments were made to arrive at US$/mmBTU figures which may be used as an indicative measure for cost comparisons.*

facilities offshore might also permit a significant cut in transport costs. This needs to be verified through further studies.

6.25. Transport costs were evaluated for two modes of transport: pipeline and CNG/LNG. In Rwanda, difficult topographic conditions inflate pipeline construction costs above normal standards which would already be high under the original concept of onshore production, given that the major fuel consumers were at distances of more than 100 km. Under the "Grands Projets", gas production costs were evaluated for four alternative locations of the production plant on the shores of the Lake and for different pipeline routes. Resulting costs of gas pipelined to, for example, the cement factory at MASHYUZA, are higher than US$9/mmBTU in all cases but one, where the cost is estimated at US$8/mmBTU. The new study on transportation referred to in para. 6.6 and 6.7 indicate that a 20% reduction in transportation costs may be attainable through a combination of CNG barging and pipeline transport, reducing the cost of supplied gas to US$7.00-7.50/mmBTU.

6.26. The new study limits itself to transportation of gas to MASHYUZA, however, and does not properly address distribution to dispersed consumers who would presumably be supplied by a combination of barge and truck. Some indicative figures on the cost of gas distributed to medium and small dispersed customers are given below. According to industry sources, CNG compression normally costs a maximum of US$1.50/mmBTU; transport of CNG costs up to US$2/mmBTU for road distances of up to 200 km (this is more than the distance between Kigali and the Lake), and CNG dispensing amounts to a maximum of US$0.50 per mmBTU. In total, gas compression and CNG supply costs add approximately US$4/mmBTU to the gas production costs estimated by the early studies (see para. 6.23). On this basis, a conservative estimate would put CNG costs to the consumer at US$7 to US$10/mmBTU. Using the reduced production costs of the 1988 study on gas module optimalization, the revised cost would lie in the lower half of this cost range.

6.27. Based on these figures and on current costs of petroleum products CIF-Kigali, the attractiveness of CNG in economic terms can be evaluated for various fuel substitution applications (see Table 6.1). Using the cement plant as an example, gas would compare quite favorably with the net CIF figure for fuel oil for industrial boilers, with a margin for uncertainties at this stage. Within a 200 km road distance from the Lake (shorter if it includes poorly paved and difficult roads) CNG has a potential as a substitute for LPG and kerosene in the small-to-medium fuel-consuming markets. With reference to the chapter on petroleum products, the present domestic consumption of kerosene--and of LPG in particular, is relatively modest (some 9% of total consumption of petroleum products in 1987). This is partly related to high prices for the two products, especially for LPG. The use of kerosene has increased rapidly in the last few years, however, and the scope for using CNG as a substitute for these imported fuels, should be considered. For applications in vehicles, CNG would probably be only marginally cost-competitive based on the production technologies analyzed thus far. Should gas production costs decrease as a result of adopting more efficient technologies, the CNG option would gain attractiveness. To the extent that potential users would purchase new equipment designed to be operated on gas, the conversion costs would no longer apply. LNG, from experience elsewhere could, in principle, be considered as an additional option to CNG. However, substantial economics of scale must be captured in order to make this type of gas conversion competitive. The likely size of the local market around the Lake does not make LNG a viable option in the foreseeable future.

Institutional Aspects

6.28. In 1975, Rwanda and Zaire signed the Bukavu agreement whereby they declared Lake Kivu gas to be their joint resource. In order to develop the resource they agreed to create a jointly-owned company, the SOCIGAZ, and entrusted a Joint Technical Commission with the preparation of its statutes. Several versions of SOCIGAZ statutes have been prepared and reviewed but agreement has not yet been reached on their final form. Successive drafts have differed widely from one another, reflecting changes in perception of the appropriate institutional and contractual context as a function of study results, project design, size, and capital requirements, etc. The role envisaged for SOCIGAZ and its statutes have varied from one extreme to the other. Thus at different times, SOCIGAZ has been envisaged with the following structure:

(a) as the monopoly agent for exploitation, transport, and commercialization of the gas as a fuel, and for its transformation into derivatives. The bi-national entity was to be fully funded and financed from official sources;

(b) as the agent of the two Governments empowered to manage the resource and to exercise the regulatory power to exploit the gas, including granting concessions to third parties, managing the shares of the two States, collecting royalties, and supplying the two cement plants.

6.29. The second structure proposed has evolved from the Mixed Technical Commission's recent recognition of the advantages of private sector involvement in developing the gas deposit and thus the need for a flexible legal structure allowing SOCIGAZ to contract with one or more private sector operators at various stages of the extraction--transport--commercialization chain. While a significant improvement over the more rigid monopoly agent approach, there are still important drawbacks to the second structure which would create a supranational authority mandated with the potentially conflicting responsibilities of both managing a natural resource and exploiting it commercially.

6.30. Within the petroleum industry, the principles governing the exploitation of a natural resource common to one or more states are those of "joint development". Through experience, joint development partners and the international legal community have come to realize the advisability of separating the resource management function from the commercial exploitation function to ensure that intergovernmental policy and diplomatic considerations are distinct from the strictly commercial considerations which are the prime concern of an exploiting enterprise. The responsibilities of resource management are usually attributed to a joint development authority which operates on the basis of a joint development treaty specifying the laws (civil, commercial, financial, safety, criminal) applicable to the area to be developed. The role of exploiting party, or operator, is normally contracted to a proven, experienced party or consortia which must first demonstrate technical and financial capabilities to carry out the proposed development, according to a development contract, in return for a share of the resource or for adequate compensation in a freely exchangeable currency. If Lake Kivu's gas is to be developed jointly, and this appears to be the intention of the two States as set forth in the Bukavu Agreement, the most recent legal structure envisaged for SOCIGAZ, as well as the latest draft statutes prepared on the basis of that structure, present two important problems to the effective realization of that principle: (a) the non-separation of the resource management and commercial functions which could give rise to conflict between competing interests and (b) the absence of a supervisory/development planning framework to spell out the numerous joint agreements of the States pertaining to applicable laws and regulations. To protect this valuable joint resource, yet ensure that commercial exploitation operations can proceed smoothly, Rwanda and Zaire should review SOCIGAZ' role and mandate with assistance from experienced legal counsel to ensure the creation of a legal and institutional structure appropriate to their joint development situation.

6.31. Pursuit of a least-cost development strategy for Lake Kivu's gas, possibly embodying offshore production and the CNG/LNG options, could present opportunities for projects of smaller size, with lower capital requirements, manageable risks, and presumably improved profitability. The possibility of attracting private investors/operators would therefore be greater. Partial or complete ownership in gas development projects, by private investors, would reduce the capital contributions and the risks borne by the Rwandan and Zairian governments. Furthermore, the participation of commercial companies from the petroleum industry as co-owners would secure the backing of such organizations and a more committed involvement of professional expertise for the development and operation of complex projects.

Conclusions and Recommendations

6.32. The comparison of the cost of gas with the cost of imported petroleum products shows that there is a potential for substitution with respect to several end-uses. However, further technical, economic, environmental, and institutional questions, as well market-related issues, need to be resolved before the gas can play the role in Rwanda's energy balance that the size of the resource might indicate. Progress on technical matters has been made in recent years, but there are still important aspects to be studied, in particular the identification of more cost-effective methods of production and transport of gas in an environmentally sound way, adapted to the context of Lake Kivu and its regional energy market. Study efforts should therefore continue toward appropriate offshore technologies as well as on the CNG/LNG option for gas supply to reasonably close small/medium fuel consumption markets.

6.33. Furthermore, the basic approach to the process of developing the resource must be addressed and decided upon and, in particular, the extent to which private companies should be invited to act as instrumental forces, together with the two governments, toward market-based solutions on the production as well as the user side. To this end, the World Bank--as an outcome of the present energy assessment--has proposed to CEPGL and the two Governments the adoption of a phased development of the gas, starting on a small but still commercial scale, which would also serve as a testing ground for possible future large-scale production and applications schemes. The phased development would be based on a promotion concept designed to attract one or more private sector companies to develop gas production under a contractual arrangement with SOCIGAZ.

6.34. The phased development/promotion strategy should include the following steps (further technical studies being carried out in parallel):

(a) an environmental study: identifying and quantifying potential risks of larger-scale gas development;

(b) a market study: focussing on the potential for substituting gas in existing uses in the vicinity of the Lake, the study would establish the scale and nature of the current and future market for gas based on the comparative cost of gas supply;

(c) legal assistance: the assistance would consist of advisory services to the two governments on institutional and contractual matters, and review of a draft development treaty and draft statutes for SOCIGAZ; and

(d) gas development promotion project: designed to attract one or more private sector companies to develop the gas, the project would be a small-scale version of the petroleum exploration promotion schemes that the Bank has implemented in a number of countries. It would consist of:

(i) the preparation of a promotion document on the gas field, including the technical options for gas production, treatment, and distribution, the immediate and potential future markets, the institutional and legal framework for gas exploitation, etc.;

(ii) the presentation of this documentation to potential investors and operators at a meeting called for that purpose or other appropriate forum;

(iii) the evaluation of the proposals received; and

(iv) the negotiation of gas production concessions, including investment commitments and production targets, fees, taxes, and penalties, repatriation of earnings and bonuses, related guarantees, etc.

VII. NEW AND RENEWABLE SOURCES OF ENERGY

SOLAR ENERGY

Resource Availability

7.1 Rwanda is well-placed in terms of solar radiation endowment: horizontal radiation averages 5.15 kWh/m^2, per day, which translates in a potential of 1.9 MWh/m^2/year. Yearly variations in radiation are modest, although effective radiation/m^2 of array surface is reduced during the dry months on account of dust. Most of the available radiation data for Rwanda pertain to extra-terrestial data, adjusted for clearness index: few actual measurements have been conducted in Rwanda itself. Only a couple of the measuring stations of the Institut des Sciences Agronomiques du Rwanda (ISAR) are equipped with heliographs or pyranometers. The University of Butare conducted some measurements in the late seventies in the Butare region (altitude 1500 m) showing variations between 3.8 kWh per m^2/day and 4.5 kWh/m^2/day. In Kinaniva (Cyangugu) a radio-transmitter is powered by 3.28 kW of photovoltaic panels, or 51 m^2 of array space. This site is equipped for detailed radiation measurements. Here recorded data indicate variations between 4.6 kWh per m^2 and 6.2 kWh/m^2. Owing to the considerably higher altitude of this location (2,145 meters), extrapolation of these values to other parts of Rwanda is not valid. Bearing in mind the occurrences of significant dust concentrations in the atmosphere during the dry months and the incomplete actual radiation measurements for the country, conservative design parameters of 3.8 kWh/m^2 for the north and 4.0 kWh/m^2 for the south are suggested by a recent Interdisziplinäre Projekt Consult, GmbH (IPC) study. 11/

Demand Parameters

7.2 Applications of solar energy currently found in Rwanda include: solar water heating (limited largely to commercial service establishments and dwellings) and decentralized ("stand-alone") photovoltaic (PV) systems for lighting, refrigeration, and sterilization mainly in the rural areas. A constraint for wider application of solar water heating (particularly in the industrial sector) is the absence of a domestic production and service capability. Attempts have been made in the past, particularly by the Centre d'Etudes et d'Applications de l'Energie au Rwanda (CEAER), with USAID funding, to encourage the local production and wider utilization of passive solar systems. Local production efforts have run into problems associated with the high cost of imported materials and the relatively weakly developed metal-working industry in the country. The latter has contributed to quality control problems in the manufacturing of the few prototypes of solar water heaters which have been produced and installed under the aegis of the CEAER program. At a cost of US$670/m^2 of collector surface, locally produced systems are considerably more expensive than imported systems. These latter systems have been largely confined to some of the larger hotels and institutional households, such as mission posts and rural

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11/ *IPC: "Planning des Sonderenergieprogrammes Rwanda", January 1986.*

hospitals. Absence of a local service capability has been quoted for the rather limited scale of utilization of this form of solar energy.

7.3 On the other hand, PV systems have found a ready market niche in the rural areas, particularly in health centers and missions. This development has been boosted significantly by considerable donor finance for this particular application: The Federal Republic of Germany is currently financing the installation of PV systems for Government health centers in the interior. This project is implemented through the Bureau des Formations Médicales Agréées du Rwanda (BUFMAR). Since the inception of this activity, 1986, some 130 installations have been effected. A typical installation consists of 2 or 3 38 peak-watt panels, regulator, batteries and lamps, providing adequate electricity for lighting purposes. The project finances 80% of system cost, with 20% to be paid for by the beneficiary institution. As the introduction of these PV systems has caused diesel-generators to become superfluous or has significantly affected the load for these sets, the project has also agreed to finance 40% of the cost of a PV system for the adjacent private households that previously were also supplied by the diesel sets. The introduction of solar powered refrigerators is currently under review by the project. A currently well-functioning design and service capability is available within BUFMAR.

7.4 Within the Etablissement Public de Production, de Transport et de Distribution d'Electricité, d'Eau et de Gaz (ELECTROGAZ), a Belgian-financed project is active to similarly disseminate PV systems for health centers in the Butare and Kigali prefectures. Rationale for the location of this project within the offices of ELECTROGAZ has been the consideration that for each specific center, the provision of a PV system is to be examined against the possibility or probability of connection to the grid. The project designs specific configurations for the respective health centers based on demand analyses. The usual configuration includes provision for lighting of the hospitals and adjacent staff houses, refrigeration, sterilization and power for telephone systems. In addition, the Pères Blancs of the dioces of Gitarama (Kabgayai) have been producing PV systems locally since 1981. The systems are geared for modest lighting requirements of rural households. Typically, one panel (19 W) would enable the use of four 8 W lights for four hours per day. Panels are manufactured locally: PV cells are imported and encased in a small workshop, which is manned by locally trained staff. Considerable experience has been gained here in the production and dissemination of small PV systems and the configuration has the benefit of employing components which have been well tested under Rwandan conditions.

7.5 Given the low energy demand in the rural areas, PV systems appear to be attractive, particularly as they are essentially modular and (unlike for instance micro-hydro systems) do not require any significant geographic concentration of demand. Calculations for the various systems found in Rwanda, however, (Table 1, Annex 5.1) show that the per kWh/cost of PV is many times above the economic cost (LRMC) of grid supplied electricity at low voltage (LV) levels (RF 15.0 per kWh, based on preliminary calculations in Annex 3.10) Costs per kWh supplied range from about RF 300 to RF 520 assuming a 20 year system life. As the cost details are not entirely comparable or may not reflect actual costs, similar calculations have been made (Table 2, Annex 5.1) for comparable systems which are commercially available on the international market. The latter calculations, allowing for freight to Rwanda, local costs and installation charges, corroborate the locally obtained data.

7.6 Two factors would reduce the very large difference between grid supplied and PV based electricity. The above LRMC is an average figure for LV distribution in Rwanda in general and does not reflect the higher distribution costs related to supplying rural areas, for which PV systems are particularly relevant. Secondly, the LRMC does not include connection costs. The increment to the LRMC due to these two factors will vary greatly with location relative to transmission lines, annual consumption, etc.

7.7 The use of PV systems for refrigeration purposes yields comparable results in terms of cost per kWh of supplied power. Comparisons with kerosene alternatives (Annex 5.2) indicate that PV systems are currently not competitive. Considerable fuel price increases could be accommodated before the competitive aspect of the kerosene refrigerator is eroded. Similarly, spillage, inefficient operation of refrigerators and allowing for considerable premium for transportation to the interior would not alter the picture. However, a more detailed comparison should also take into consideration the cost of spoilage of medications and vaccines owing to refrigeration malfunctions. Kerosene refrigerators in Rwanda have been reported to be prone to break-downs: the required temperature level can only be achieved with properly maintained refrigerators. Reduced dependability has also been thought to be the consequence of the varying and often poor quality of the kerosene actually supplied. Although quality control measures with respect to kerosene supplied could obviate some of these problems, the costs of such measures would have to be allowed for in the calculations. More importantly, the comparison implicitly assumes that kerosene is always available as required: in terms of vulnerability to irregular supply of kerosene, the solar powered refrigerators would have a qualitative advantage.

7.8 Small PV systems for lighting, although expensive in terms of cost per kWh, compare more favorably with grid-supplied electricity in financial terms. Given the current connection fees, approximately RF 50,000, and tariff structure of ELECTROGAZ, the smaller systems (say, "GITARAMA" and "R&S" varieties in Annex 5.1 ranging between RF 66,000 and RF 82,000 (US$880 and US$1,100) in system cost can be financially attractive in present value terms, based on a life-time for solar systems (and hence basis for comparison) of say, 10 years. A tariff increase to the level of the LRMC referred to in para. 5.57 would give the smallest PV system quite a clear advantage from the consumers' point of view. See Annex 5.3. 12/ Even if the connection fee were to be lowered (Annex 5.3, Case II), which possibly would lead to an increase in average tariffs above currently calculated LRMC levels, small PV systems might, under certain limited circumstances, remain attractive. Given a connection fee of only RF 10,000 and an average tariff of RF 20.5/kWh, the present values of avoided electricity charges would be higher (assuming life-time is 16 years or more) than the lowest cost PV systems.

7.9 For private households with modest electricity demands (lighting, radio only) in the grid-supplied areas, PV systems are basically attractive only provided mechanisms can be identified and implemented to spread the initial system cost over a number of years. For private and institutional

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12/ *However, when considering solely the up-front cash outlays, only one of the PV systems can compete with grid-supplied electricity. Low savings and lack of funds on the part of households will thus reduce the options that they realistically have.*

households (with modest energy demands) outside the grid-supplied areas, PV systems are clearly an interesting option. This would particularly apply to service households such as hospitals, mission posts and social centers.

7.10 Annex 5.4 gives estimates for the contribution solar energy is currently making to the overall supply of energy in Rwanda. Although the estimates imply an annual rate of increase of 22% in the contribution of solar to total energy supply (1980 = 0.3 GWh), the actual amount of 1.5 GWh falls far short of the earlier Société Nationale d'Etudes de Projets (BUNEP) 13/ projections of 17 GWh for 1986. This projection was based on the establishment of a factory for the production of solar water heaters which would have produced and installed some 16,000 m^2 of collector surface in the country by 1986. The estimated 1.5 GWh constitutes some 1.3% of total estimated electricity consumption within the Rwanda network in 1988.

Recommendations

7.11 Given the relative attractiveness of small PV systems to supply small but critical quantities of electric energy in the rural areas of Rwanda, it is recommended that measures be considered which would facilitate the wider dissemination of such systems. Specifically, the viability of a revolving fund for the financing of the acquisition of PV systems should be sounded, for example, through the participation of the Banque Populaire du Rwanda with its decentralized network. The assessment would focus on the structure of the potential demand for such systems in the non-grid supplied rural areas. Apart from the specific energy demand patterns, the study should also estimate the repayment ability of selected households (households with salaried personnel, small commercial establishments, etc.). Furthermore, the study would seek to identify specific households in grid supplied areas which could be considered for the installation of PV systems. The tariff policy of ELECTROGAZ would be taken into account, since a commitment to a PV system would inherently limit the energy demand of households that might otherwise (given lower connection charges) prefer to have their demands met through the grid.

7.12 On the supply side, efforts should be made to identify typical PV configurations which (a) have already been market-tested in Rwanda or in neighboring countries and, (b) would be most cost-effective. This leads to the issue of donor-financed and donor-subsidized installations which are currently competing directly with locally manufactured products. In the light of the above recommendations, it should be ascertained whether the respective products are perhaps serving separate markets, or whether specific measures could be introduced which would effectively ensure the targeting of the local products to markets distinct from those supplied by the donor community. One distinction would be between the economically better situated private households and rural institutions. Given the low degree of penetration of passive solar systems, it is also recommended that specific measures be studied which would encourage the conversion from electric or gas-fired heaters to solar water heaters. Import levies and the creation of a local service capability need to be examined in this respect.

13/ *Study published in 1982 by Bureau National d'Etudes des Projects (BUNEP) and Ecole Polytechnique Fédérale de Lausanne (EPFL): Etude du Secteur Energétique au Rwanda.*

MICRO-HYDRO POWER

Resource Availability

7.13 Several studies have been conducted into the potential for micro-hydro power (less than 1 MW) in Rwanda. The BUNEP/Ecole Polytechnique Fédérale de Lausanne (EPFL) 1983 study investigated several sites within the context of exploring energy supply options for rural centers. Subsequently, other sites were investigated by CEAER and by the Société Hydrotechnique de France. The mission was further supplied by MINITRAPE with an inventory of potential micro-hydro power sites. This information formed the basis of the list in Annex 5.5 which details the sites in terms of location and other basic parameters. Essentially, the identified potential is located in the western part of the country. Twenty-six or nearly three quarters of the sites would yield power below 50 kW. Together they would account for 18% of power identified, or 24% if the largest single site, Nyamutera of 850 kW is omitted. One of the sites listed, Nkora (Gisenyi) is actually now being operated by the Office des Cultures Industrielles au Rwanda (OCIR) after rehabilitation work in early 1987 under an IBRD-financed coffee rehabilitation project. This scheme and other systems currently in operation are summarized in Table 7.1.

Table 7.1: MICRO-HYDRO POWER PLANTS IN OPERATION

Location	Installed Capacity (kW)	Year of Commissioning	Operator
Kilinda	65	1973	Hospital
Murunda	108	1979	Mission
Nkora	150	1981	OCIR
Pfunda	103	1971	Tea Factory
Runyombyi	120	1973	School

Source: IPC (1986); BUNEP/EPFL.

7.14 Colombani (1988) 14/ provided an annotated update of the sites previously identified in Bwanakeye & Colombani (1985). 15/ The 1988 study was commissioned by United Nations Development Programme (UNDP) as a pre-formulation exercise for a project which has been retained for financing jointly by UNDP and the United Nations Capital Development Fund (UNCDF). Tentative costing of this project is US$2,500,000 to be shared by the Government of Rwanda, UNDP, and UNCDF. The scope of the project is technical, economic and financial appraisal of 8-10 of the sites identified by Colombani, and subsequent construction of plants. An overview of the sites in question is provided in Annex 5.5. Some of the sites may be excluded from the UNCDF financing on account of limited capacity. The largest site identified by Colombani, Mwogo, 183 kW, could possibly be

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14/ J. Colombani: *Rapport de Mission Pré-Formulation/Faisabilité pour la Construction de Microcentales Hydro-Electriques au Rwanda. 1988.*

15/ J. Bwanakeye et J. Colombani: *Inventaire des Sites de Microcentrales Hydro-Electriques au Rwanda. 1985.*

considered for grid connection. Although the costs per kWh calculated by Colombani compare well with his estimates of grid-supplied electricity (RF 78/kWh, for a 10 kilometer [km] connection) or generator supplied electricity (RF 50/kWh, diesel), it should be noted that the assumptions on which the cost calculations are based are yet to be verified. The hydrological parameters of the various sites are based on incidental and ad hoc measurements: no time series of flow-data for the sites exist. Estimates of construction costs are also purely notional: no empirical reference data is used. The amortization period of 35 years used should be considered excessive; the Nkora plant, recently rehabilitated, demonstrate that the considerable amounts of solid matter in the rivers could seriously shorten turbine-life of small hydro systems. Especially for the high-head schemes (>50 meters) the sedimentation issue is critical.

Demand Parameters

7.15 The pattern of energy demand in Rwanda as shown in the BUNEP/EPFL study indicates essentially low per capita demand outside the urban centers. If costs of micro-hydro are not to become prohibitive in terms of connection costs and losses, a certain extent of concentrated demand is a prerequisite for viable operation. This would suggest the rural centers as possible points of focus for micro-hydro development. However, the demand in these centers is also low. It is estimated that typical demand in a given rural center will lie between 40 and 100 MWh per annum. Typical rural centers would have in one location: a health center, a mission post, a hospital, a school, a community center, three workshops and some 50 households demanding electricity. If these demand constraints are applied to the Colombani data, the required break-even price per kWh actually supplied should be multiplied on average by a factor of almost 5 as average output in the Colombani sites is optimistically put at 340 MWh/year. 16/

Issues

7.16 The main issues to be addressed appear to be as follows: the inventories of potential micro-hydro sites are based on scant hydrological and pluviometric information. If the potential is to be realistically assessed, these baseline parameters need to be verified and strengthened considerably. Possible effects of sedimentation on expected life-time of plant and hence on costs should also be taken into consideration.

7.17 Full economic construction costs of plant should be allowed for: the Bwanakeye/Colombani approach is to assume that construction and operation could to a large extent be left to community labor. This may or may not be valid, depending on the particular site, but in general the costs should be explicitly included in the analyses. Institutional issues pertaining to effective maintenance and operation of plant should also be addressed if communities are to be responsible for the actual operation of micro-hydro plant. In the final analysis, high costs as such of micro-hydro

16/ *The factor of 5 is arrived at by dividing the optimistic figure of 340 MWh/year by the average of the more realistic range of 40-100 MWh/year.*

development often turns out to be the main issue which renders this alternative non-competitive. Careful selection of a limited number of sites to be studied is therefore necessary.

7.18 For the individual sites in question, a thorough analysis must be made of the specific pattern of demand existing and likely to develop in a given location: it cannot be assumed that emphasis on energy supply parameters alone is adequate and that the very availability of electric power in itself would lead to the concentration of activities requiring power, such as workshops, etc. Proximity of the proposed sites to the ELECTROGAZ grid is also an important factor to consider: the application of an "average" distance to the grid is inadequate. This also leads to the issue of institutional arrangements. At the moment, the center of gravity for the development of micro-hydro appears to be MINITRAPE. Effective mechanisms are, nevertheless required to ensure that development of micro-hydro is constantly related to the possible applicability of other energy options (particularly solar, given the low demand) and the development plans of ELECTROGAZ in terms of rural electrification. A priority task for such institutional co-operation is the early determination of specific sites currently considered for micro-hydro development, which are already, or can be expected to be in the near future, close to the grid.

Recommendations

7.19 Given the many serious issues involved, it would be uneconomic to pursue simultaneously the development of the 8-10 micro-hydro sites as proposed by UNDP/UNCDF. As a preliminary step, for all the sites considered, it is recommended that:

(a) the nature and the availability of the hydrological and pluviometric data be ascertained;

(b) proximity to the existing grid, or likely proximity to the future grid, be considered;

(c) an inventory be made of likely demand for power in the given locations.

On the basis of these criteria, one or two sites should then be selected for further examination and possible development as pilot plants. Concurrently, programs should be formulated for hydrological data gathering for other sites, and minimum information requirements for further site developments should be defined.

BIOGAS

Resource Availability

7.20 Endowment parameters for biogas production are modest: global availability of suitable raw materials is sufficient, but often prevailing low temperatures militate against efficient digestion. More importantly, low average per-household cattle holdings plus the absence of a biogas tradition are further obstacles.

Supply and Demand Parameters

7.21 Production of biogas in Rwanda has been pursued by CEAER and MINITRAPE since about 1982. Energie des Grands Lacs (EGL) has also co-operated in these efforts. Of the 30-odd plants constructed, few seem still productive. Plant-abandonment has either been a result of (a) poor construction and hence gas leakages, or (b) poor ratio between effort and maintenance on the one hand and gas output on the other hand. Current efforts seek to promote and disseminate a German NGO-financed design consisting of: stable, digestor and cistern. The stable should minimize collection difficulties of raw material; the cistern should ensure availability of water during the dry season. The design is expensive: a "floating dome" version, recently constructed was reported to have cost RF 335,000. According to the Annual Report of MINITRAPE the designs vary in costs between RF 230,000 and RF 290,000. The least expensive design, can reportedly be implemented for less, once the training of personnel has been completed (now included in the costs). Quoted cost of materials alone is RF 140,000. Extensive calculations by IPC (1986), at an investment cost of RF 70,000 (i.e., half of cost of materials for the design currently propagated), found biogas to be more expensive than available alternatives.

7.22 The Government is optimistic about the future of biogas plant propagation in Rwanda and appears to be placing great emphasis on the biogas program. However, if the development of the program is to be targeted at the typical rural family, two fundamental parameters would appear to stand in the way of significant success for the program. Firstly, given Rwandan climatological conditions, three to four animal units (one animal unit defined as 250 kg live weight) have been found to be required for the production of 1.5 m^3 gas/day, which is a basic minimum for the energy needs of a small household. Actual surveys conducted under the auspices of a GTZ-financed project in the Nyabisindu area found that less than 50% of the households had cows at all. On average, 0.6 cows were counted per household. 3.5% of households had more than 4 cows. With data from the National Agricultural Survey of 1984, and converting average animal numbers to animal units (cow = 1.0, goat = 0.1, sheep = 0.1, pig = 0.3), this yields a national average of 1.04 animal unit per cattle farming household. By prefecture, these numbers would range between 0.4 for Cyangugu and 1.5 for Gikongoro. These averages would suggest that the percentage of farming household possessing the 3-4 animal units required for biogas production is a very small minority indeed, corroborating the Nyabisindu findings quoted earlier.

7.23 A second important parameter to be considered, given the Government's emphasis to have the farmers effectively participate in the construction and the running of the biogas plants, is average household expenditure of energy. According to the "Enquete Nationale sur le Budget et la Consommation" (Milieu Rural), by the Ministère du Plan (MINIPLAN) from May 1988, average energy expenditure in the rural households is RF 565 per annum (RF 210 thereof represented by kerosene, RF 85 referring to forms of barter or exchanges, and RF 270 referring to energy and water purchased). This survey excluded expenditure on fuelwood. Estimates of the value of fuelwood consumption are contained in a separate survey. 17/ The Value of final consumption of fuelwood in 1983 was estimated at RF 1,640 million; value of labor invested in collecting the fuelwood is put at RF 2,385 million. Given an estimated population of 5,529,000 for that year and average rural household size of 4.9, total value of fuelwood consumption would be RF 3,567 per household. Combining the two survey results yields total energy household expenditure of RF 4132 per annum. Obviously, even if biogas plants could be obtained for RF 70,000 and if they could be amortized over a period of 10 years, resulting annual charges of over RF 7,000 compare unfavorably with household energy expenditure. Again, at best a small minority of rural households would have the means to meet the expenditures related to biogas plants.

Issues and Recommendations

7.24 A critical issue is therefore the determination of the approximate size of the small minority of rural households which meet both the criterion of sufficient animal units and adequate income to meet expenditure related to the construction of a biogas plant. If it can be determined that this target group is still sufficiently large to warrant the attention currently given to the propagation of biogas, other issues such as the economic viability of biogas versus other options, institutional support, training, extension services and socio-economic acceptance still remain as serious obstacles. Certainly, if it is determined that the development of biogas is to be pursued all the same, it would be worthwhile to conduct a thorough examination of the biogas installations which have been erected in Rwanda and to systematically catalogue the reasons for failure or success. The examination of recent experiences (IPC, 1986) indicates that even the qualified staff of the Animal Husbandry Research Station of the University of Butare abandoned the plants because of difficulties of operation, leakages and generally poor production. In conclusion, therefore, due to the restricted natural scope for development of biogas in Rwanda, no public resources for this purpose should be allocated and a regional approach to outstanding issues should be sought.

WIND ENERGY

7.25 Available wind measurement data indicate that Rwanda has a wind-regime which is uninteresting from an energy perspective. Four times daily readings, at a height of 12 meter, are available for stations in Kigali, Butare, Gisenyi, Ruhengeri and Karenge. For the Kigali area, 15% of the yearly frequency of observed velocities exceed 3 m/s; 7% exceed 5 m/s. For the Gisenyi area, these percentages are respectively 23% and 18%. The high percentage of windless days (35% of readings) is a further phenomenon to be taken into account here. Given the topography of the country, the existence of interesting micro-climates cannot be ruled out, but globally speaking, wind as an energy resource does not have practical significance. Wind-driven electricity generators have been attempted in a sporadic manner. No systems are currently in function.

17/ *C. Muller, ENBC, "Approvisionnement en Eau et Bois de Feu". April 1988.*

Conclusions and Recommendations

7.26 New and renewable energy technologies have had limited applications in Rwanda, despite an environment of quite good resource endowment for certain alternatives and high conventional energy cost. Government-supported efforts have been dispersed over a wide range of technologies, and have been limited to research development and small-scale testing.

7.27 The alternative energy sources discussed in this section are not likely to provide substitutes for traditional or modern energy sources on any significant scale in the near future. In terms of chief energy requirements of the population, cooking, both solar and micro-hydro offer negligible potential, for technical, cost and socioeconomic reasons. Theoretically, biogas could be impacting on this requirement; however, as indicated this alternative is limited to the more affluent rural households. On the other hand, both PV and micro-hydro systems would appear to offer practical potential of a certain extent for other energy requirements, particularly for rural institutions like dispensaries and schools in more isolated areas. It must be emphasized, however, that most new and renewable energy options are non-economic at present-day technologies and international energy prices. A selective attitude and limited use of public resources are therefore recommended.

7.28 With respect to the individual types of energy the following recommendations are made:

(a) For PV systems, the justification of establishing a revolving fund for example, through the participation of the Banque Populaire du Rwanda, for financing the acquisition of solar units should be studied, on the basis of the demand pattern and payment ability, particularly in non-grid supplied rural areas. Also, the supply side should be examined, specifically the issues of technical support for local production of cost-effective installations as well as coordination of donor-financed systems that compete with the former.

(b) With respect to micro-hydro power, a selection of one or two sites among the ones so far identified, should be made for further study and possible development as pilot plants. The selection should be made on the basis of sufficient data on hydrology, on an inventory of realistic demand related to affordability, and on the proximity of the demand area to the grid. A program for the collection and analysis of baseline parameters regarding the identification and selection of sites in the future should be established.

(c) As for biogas, the restricted natural scope for its development in Rwanda indicates that no public resources for this purpose should be allocated and that further efforts could best be pursued through EGL on a regional basis.

(d) The New and Renewable Energy Division of the Direction de l'Energy in MINITRAPE has the formal responsibility for the planning and follow-up related to alternative energy sources. In terms of actual development work, CEAER located in Butare at the

University of Rwanda, is the focus of research and testing in this field. It is recommended that:

(i) MINITRAPE give more active consideration to the development of PV and micro-hydro systems and to the coordination of the various donor activities in this respect;

(ii) issues related to rural electrification be the subject of regular discussions at working group levels between MINITRAPE and ELECTROGAZ, to ensure exchange of information and coordination of work related to micro-hydro power and planned grid extensions.

VIII. ENVIRONMENTAL ASPECTS OF VARIOUS ENERGY SOURCES

Background

8.1 Environmental protection and management has a long history in Rwanda. On the one hand, this is due to the specific situation of the country and the problems created by the relationship between population and natural resources. On the other hand, the Rwandan government has played an active role and has had a very early perception of its responsibilities in this field. Examples of this is the fact that the Rwandan government for many years has included soil conservation measures in its agricultural extension package and that the community tree plantation efforts have been amongst the most effective in poor countries. Also, the population increase was, a long time ago, identified as a major issue and the Office National de la Population (ONAPO) was created in 1980.

8.2 Briefly, some main characteristics that form the background for environmental concern, in Rwanda, are as follows:

(a) Rwanda stands out among African countries for its high population density. This can be expressed by various ratios: the average population density on the total physical area of the country is high, over 250 inhabitants/square kilometer (km^2), the highest in Sub-Saharan Africa. Population density on cultivated land is much higher: the available land per farm family is presently estimated at 1.2 ha and is expected to decrease to 0.7 ha/family by 2005. These average figures hide wide regional variations and some areas have densities approaching 1,000 inhabitants/km^2;

(b) the low proportion of cultivable land is mainly due to the topography of the country: very little flat land other than the "marais" (marshlands) can be observed nationwide. Apart from the cultivation aspects, this has impacts on the land's susceptibility to erosion, as rainfall is abundant, especially in some seasons. Rwanda has recently experienced increased erosion because of deforestation and intensive cultivation. A combination of declining natural land productivity and population growth will make food production an increasingly difficult task in the future in Rwanda. It has been estimated that per capita food availability will decline from 814 kg/capita/year in year 1970 to 611 kg/capita/year in year 2000 if vigorous measures are not taken;

(c) the fauna and flora of Rwanda, though not really unique, have some interesting features that make them very valuable from a conservation point of view.

8.3 The Rwandan government has decided to prepare a National Environmental Strategy (NES) as well as an Environmental Action Plan (EAP), with the assistance of external donors. 18/ Three preparatory missions visited Rwanda between November 1987 and November 1988. The latest mission produced the following conclusions and recommendations:

- a study will be conducted to complete the preparation of the NES. It is due to commence in 1989. As an outcome of the third donors' mission, the study will incorporate the preparation of an EAP as a logical consequence of the NES design process; and

- a National Steering Committee for the study will be created: it will be composed of the director generals of the key ministries involved in the study (including the Presidency) and will supervise the execution and completion of the study. Particular attention will be given to the analysis of various institutional issues raised by the study.

8.4 At present, the Rwandan government is active on environmental issues particularly in the sectors shown in Table 8.1.

18/ *EAPs are currently being prepared in several countries, both in Africa and in other continents. This is the result of initiatives taken by the governments with the assistance of the World Bank and the United Nations Development Programme (UNDP). In essence, the basic idea behind the EAPs as well as their concept is very similar to that of Energy Assessments. In both cases, the objective is to draw a global picture of current issues and options in the sector, and to make recommendations for future action within a coordinated and efficient framework.*

Table 8.1: SUMMARY OF SELECTED ENVIRONMENTAL ACTIVITIES IN RWANDA

Intervention categories	Main Rwandan institutions	Examples activities	Main Partners: USAID	Switzerland	France	Fed.Rep Germany	Belgium	Canada	Europe	World Bank
Soil conservation	DCS (MINAGRI)	RRAM	X		X	X				
Soil fertility	DGPA, DCS	Fertilizer Project	X		X	X	X	X		X
Natural forests	DGF/ORTPN	Mountain Forest		X	X				X	X
Reforestation	DGF	GBK	X	X					X	X
Agroforestry	DGF	PAP Nyabisundu	X	X		X	X	X	X	X
Waters	DGEau, DSE	Water Supply (Leva)		X	X	X				X
Lowland development	DGEau, DGR, MINIMART	"Petits Marais"	X					X	X	X
Energy	DGE	Kivu Lake Methane					X		X	X
National parks	ORTPN	Akagera Nat. Park					X			
Ecological tourism	ORTPN	Akagera Nat. Park					X			
Urban environment	MINISAPASO, MINITRANSCO	Urban Planning								X
Research	UNR, INRS, ISAR	Forest Sc. Res. Prog.	X	X		X	X	X		X

DCS = Direction de la Conservation des Sols
DGF = Direction Générale des Forêts
DGPA = Direction Générale de la Production Agricole
DSE = Direction de la Santé et de l'Eau
GBK = Gishwati-Butare-Kigali
INRS = INRDS
ISAR = Institut des Sciences Agronomiques du Rwanda
MINAGRI = Ministère de l'Agriculture, de l'Elevage et des Forets
MINIMART = Ministère de l'Industrie, des Mines et de l'Artisanat
MINISAPASO = Ministère de la Santé Publique et des Affaires Sociales
MINITRANSCO = Ministère des Transports
ORTPN = Office Rwandais du Tourisme et des Parcs Naturels
PAP = Projet Agro-pastoral
RRAM = Regional Resource Management
UNR =

Source: World Bank, USAID, Joint Donors' Mission (March 1988).

Relationship Energy-Environment by Energy Source

Petroleum Products

8.5 Except for small quantities of methane gas, Rwanda does not produce petroleum products. Besides, it is a land-locked country. Consequently, the main activities associated with petroleum products are the road transportation, the storage, and products utilization. The environmental aspects of these activities are limited to occasional risks: mainly road accidents leading to liquid spills and storage hazards. No major accident has been reported to date. The main risks are obviously in Kigali, the capital city, where most of the demand is concentrated. However, some industries have to buy and store large quantities of petroleum products. The choice of storage areas needs to be made carefully. The recent decision to place new storage tanks near the Etablissement Public de Production, de Transport et de Distribution d'Electricité, d'Eau et de Gaz (ELECTROGAZ) Gikondo substation was not optimal, since power lines running overhead could, if downed, ignite products being stored. No legislation exists covering the risks associated with petroleum products transportation and storage, and more generally urban and industrial risks. A general trend in developed countries is to request industries and local governments to design and implement mechanisms to prevent accidents. A country like Rwanda will have to investigate the relevance of creating such legislative tools.

Hydropower

8.6 In general, hydropower investments, especially when they are of a large magnitude, are expected to have a significant and usually detrimental environmental impacts, especially on aquatic fauna. In the case of Rwanda, power is mainly supplied from four hydroelectrical plants with a total installed capacity of 26.5 MW and with two of the power stations dominating: Mukungwa (12.5 MW) and Ntaruka (11.3 MW). The Government has made constant efforts to maximize domestic power production and minimize power imports from Zaire. This has often lead to operating hydropower plants beyond their rated annual available production. This practice has steadily lowered lake levels over time. Lake Bulera, which supplies the Ntaruka plant fell by about one meter between 1962 and 1973 and by three meters between 1973 and 1987. The level of Lake Ruhondo, which supplies the Mukungwa plant, has shown a steady decline during the years 1983-88, except for 1986, by a total of 0.4 meters, again due to over production. Apart from fluctuations in lake levels and the associated impact in river hydrology, the impacts of hydropower plants on the aquatic ecosystems have not been studied in detail.

8.7 The decline in the level of Lake Bulera is due to drainage through a man-made canal and to operation of the Ntaruka power plant at a capacity exceeding the lake's water replenishment capability. The Government's interest in obtaining the maximum output from Ntaruka, thus in increasing the waters of Lake Bulera, led it to commission a study on this subject which was completed in early 1988. In addition to sealing off the man-made canal, which was actually done by ELECTROGAZ in 1987, the study looked at the possibilities of stopping water flow from the lake which feeds marshes contiguous to the lake and at diverting run-off water from volcanoes surrounding the lake. The study concluded that completely stopping the water flow into the neighboring marshes could result in a loss of water for Lake

Bulera, and that a partial reduction of water flow into the marshes would have little, positive effect on increasing the water of Lake Bulera and therefore be only marginally beneficial for operation of the Ntaruka plant. The study points out, however, that possible additional benefits from agricultural exploitation of drained marsh areas would need to be taken into account, but does not quantify them; no mention is made of the environmental impact of such proposals.

8.8 The solutions recommended by the final version of the study include (a) improving the canal closure, as the 1987 structure still allows some water to escape, and (b) diverting run-off from the south sides of three surrounding volcanoes. In reality, benefits from the first option are likely to be small, since sealing off the canal has not in itself made a substantial diff ence in the lake's recovery. Benefits attributed to the second option would be an increase in Ntaruka's production as well as that of the downstream plant, Mukungwa I. Capital costs of the second option would be US$960,000 (using open canals) or US$2.44 million (closed canals) with the first alternative having a substantially higher maintenance cost. Internal rates of return on both alternatives of the second option are in the 20% range. While there are no negative environmental effects from elimination of the artificial drainage canal, the effect of diverting the volcanoes' run-off is not certain. Furthermore, the costs of this option are not well-defined, making the rate of return very tentative. Additional studies to determine the environmental impact of diverting run-off and to obtain better costs should be made before any decision is taken.

8.9 The Rwandan government intends to build several new power plants during the next decade. Too little is known, however, about the environmental impacts of hydropower plant construction, operation, and maintenance. All new major projects should be subjected to sound environmental impact assessments procedures of a quality that is of international standard. Furthermore, environmental effects should be given due consideration among the factors assessed in the choice between national and regional power projects.

Wood

8.10 Wood is used in Rwanda as a cooking fuel by the vast majority of households, especially in rural areas. This, in addition to other uses of wood--charcoal production in particular--places a high pressure on forests and tree resources. Rwanda is in the same situation as many African countries, where the "logical" utilization of forest and tree resources for timber and other high-value uses is minimal and where low quality products like firewood are consumed in such large quantities that the sustainable wood supply is not sufficient to meet the needs, resulting in partial deforestation. Though data quality is very poor, woodfuels balances have been computed for various prefecture areas in Rwanda (Chapter III). In four of these, there are at present woodfuel deficits. Projections of demand and supply indicate that although the number of prefectures with such deficits may be reduced to three by year 2000, the overall deficit for Rwanda may well double compared to today. Technical measures are not enough to cope with a trend that is largely determined by population factors, and Rwanda will have to react to a situation where, during the next decades, the forest and tree cover will decrease, with associated detrimental environmental impacts increasing (soil erosion, loss of habitat) as well as economic impacts (decreased soil fertility, loss of "secondary" products from the forest). Population growth is directly responsible for this degradation and, unless effective measures are taken in this respect, technical approaches will only yield marginal results. In the meanwhile, projects dealing with improving the efficiency of resource management, by-products recovery, end-use of wood as a fuel, will be necessary to minimize the present destructive trends. Chapter III of this Report, on biomass and household fuels, describes ongoing and planned activities in these areas.

Charcoal

8.11 Charcoal is the favorite cooking fuel in urban areas. As the population in urban areas grows faster than in rural areas, it is widely expected that the consumption of charcoal will increase faster than that of wood. The environmental impacts of charcoal production are related to the cutting of trees, as mentioned in the previous section. These effects are amplified, however, due to the commercial nature of charcoal operations, thereby putting greater strain on forest resources. As indicated in Chapter III this has had detrimental consequences in certain regions, to which the Government has reacted by encouraging a shift of charcoal production away from savannah areas to areas with plantations. In Chapter III recommendations are made to improve the overall efficiency of the charcoal production-utilization system. This is strongly required because of the population trends described above. But it should be stressed that regardless of the improvements introduced, the overall efficiency of production and consumption of charcoal will remain such that it creates a wastage of energy compared with the direct utilization of wood. Unfortunately, social and economic conditions are such in Rwanda, as in most other African countries, that it will be very difficult to arrest or even reduce specific charcoal consumption. For the time being, the second-best appears to be improving the charcoaling efficiency and the charcoal cooking stove efficiency. In the long run, economical alternatives to charcoal cooking should be investigated. The research should involve both technical (hardware) and social sciences specialists.

Papyrus

8.12 Papyrus briquettes are being investigated as a possible alternative fuel to charcoal. Pilot projects are being conducted. Chapter III describes these projects and identifies the main issues, including the lack of appropriate economic/financial assessment of the papyrus harvesting, processing, and transportation elements. With respect to environmental aspects, the development of papyrus briquettes as an alternative fuel appears to be advisable, on the following grounds:

(a) papyrus is harvested in lowlands (known as "marais" in Rwanda), and this activity could form part of a global strategy aimed at conserving the "marais", presently threatened by the heavy agricultural and general land pressure in Rwanda. These "marais" are essential components in the total environmental picture;

(b) papyrus is a renewable resource at the human time scale, i.e., its rate of renewal accords with its rate of depletion. The yields studied by the various teams of specialists involved have shown that the rate of exploitation could be as high as 30 tons/ha/year without depleting the resource. The average yield has been found to be around 15 tons/ha/year, a very sizeable quantity for fuel production. The cost-competitiveness of papyrus briquettes, needs to be studied, however, and is dependent on the establishment of efficient production lines, as mentioned in Chapter III;

(c) the extent of available papyrus land is presently large, even at the doorstep of Kigali;

(d) harvesting is done on a rotating basis, so that parts of the papyrus areas can still play their role as fauna habitat while others are being harvested; and

(e) methods used to harvest papyrus are all manual, which prevents major impacts on the lowlands.

Papyrus would thus appear as a recommendable fuel on environmental grounds. However, as is the case with environmental conservation, in general, the development of papyrus exploitation must remain under control, otherwise all the above advantages might be turned into drawbacks. Given the development period required, no major problem should be expected to arise during the next two decades or so.

Peat

8.13 Peat resources are very large in Rwanda. Though no precise inventory has been conducted, figures commonly quoted are 5 to 50 million tons of proven resources. The Government has undertaken pilot projects to investigate the technical, economic, and financial feasibility of extracting peat from some of the wetlands, with two categories of outlets in mind: industrial and household uses. Though certain types of industrial utilization might prove economic (e.g., the cement plant of MASHYUZA), household utilization as a cooking fuel does not appear promising from either a practical or from an economic point of view. On top of that, the environmental impacts of peat exploitation are generally detrimental. Peat is not a renewable resource at the human time scale. Alterations of the peat layer is thus a non-recoverable encroachment on the ecosystems. In Rwanda, like in other parts of the world (e.g., Ireland), peat bogs perform important ecological functions and are used as habitat by a variety of flora and fauna forms of life. Their destruction is bound to imply the loss of the functions, habitat in particular, performed. It is therefore recommended to include a comprehensive environmental impact assessment of any major peat extraction development plan and generally to investigate the potentials of other energy sources before considering large scale exploitation of peat resources in Rwanda.

Methane Gas

8.14 Methane gas can be obtained from two sources in Rwanda: animal by-products and extraction from the deep waters of Lake Kivu.

(a) Animal by-products are a scattered source of energy which, because of the low development level of the technology in Rwanda and in Africa in general, will not generate significant quantities of useful energy during the next decades. In Chapter VII on new and renewable energy sources it is estimated that endowment parameters for biogas (a gas mixture comprising approximately 60% methane) production are modest and that, altogether, the chances for a development on a broader scale are small. Under these circumstances, the question of environmental impacts of animal by-products biogas production is rather academic. In general, the development of this type of technology is seen as having rather beneficial environmental impacts, as it creates the conditions for improved organic matter management, the only slight risk worth noting being that of gas explosion in the households. But there is no evidence of serious damages from this, even in countries like China where millions of bio-digesters have been built and operated.

(b) Several studies have been carried out on the subject of risk related to the production of methane gas from Lake Kivu. This has been and still is a controversial issue. The main features on the risk assessment are given in Annex 6.1. Put briefly, it is quite possible that with improved technologies and the resolution of institutional and legal issues, methane exploitation on a commercial scale can commence in the medium term. Experts do not agree, however, on the risks associated with methane exploitation in Lake Kivu, but the latest study 19/ concludes that the probability of methane surface explosion is extremely small and that works could go ahead. It is recommended by the mission that an impact assessment and a detailed monitoring system of the environment in the Lake Kivu area should be designed and implemented in relation to any further gas development.

Relationship Energy-Environment by Region

8.15 The environmental impacts of the energy policy are bound to be specific to each particular location in Rwanda. In geographical terms, several places are likely to experience these impacts with various intensities. The main concerns in this respect are as follows.

(a) Lake Kivu. The area will possibly be a site for a major investment in the field of methane extraction and transportation. In spite of the limited risks involved, according to the latest studies, it will be necessary to refine the conclusions with a proper environmental impact assessment prior to any major investment.

(b) Woodfuels balances by prefecture. The woodfuel balance (demand compared to sustainable supply) is presently negative in four prefecture areas of Rwanda: Kigali, Butare, Gikongoro, and Ruhengeri. By year 2002, the number of prefectures experiencing a deficit may have fallen to three (Kigali, Butare, and Gikongoro) but the magnitude of the cumulated deficit could be much larger, reaching close to 20% of the demand compared to some 15% in 1987. Annex 1.7 shows the extent of surplus/deficits for each prefecture area in Rwanda.

19/ *Haroun Tazieff: "Opportunities and Risks for Exploiting Methane"; 1988.*

(c) The role of Kigali. Because population density is directly linked to environmental impacts, the role of Kigali will be critical. The charcoal demand largely determines the forest problems and projects in the rest of the country. Kigali prefecture area itself shows an unbalanced woodfuels situation where demand exceeds the sustainable supply. Moreover, this gap is bound to increase in the future. As a concentrated energy demand center, Kigali suffers from all associated risks including the possibility of accidents linked with petroleum products storage and distribution.

Conclusions and Recommendations

8.16 Table 8.2 presents a summary of possible impacts and major risks linked with the various energy sources in use at present or expected to be used in the near future in Rwanda.

Table 8.2: SUMMARY OF ENVIRONMENTAL IMPACTS OF ENERGY SOURCES DEVELOPMENT IN RWANDA

Energy Source	Impact magnitude	Risk	Economic importance
Petroleum products	-	-	+
Hydropower	--	-	+
Wood	--	--	+++
Charcoal	---	---	+
Papyrus	-	0	(+)
Peat	--	-	(+)
Methane from animal by-prod.	+	0	0
Methane gas from Lake Kivu	-	--	(++)

Notes:

Impact magnitude		Risk		Economic importance	
---	Very detrimental	---	High	+++	Very important
--	Detrimental	--	Some	++	Important
-	Slightly detrimental	-	Slight	+	Some importance
0	Neutral	0	None	0	No importance
+	Slightly beneficial			( )	Potential

Source: Mission estimates.

As can be seen, charcoal, wood and methane gas from Lake Kivu are the most important energy sources as regards the seriousness of environmental impacts because of their economic significance and of the risks/impacts associated with their utilization. These resources therefore require particular attention with respect to environmental issues.

8.17 Concern has been raised, in several connections in this Report, that the population growth will indirectly create major ecological imbalances in the short term. The Government is conceptually very aware of this and have emphasized this issue on several occasions, including giving environmental responsibilities to the Ministère de la Santé Publique et des Affaires Sociales (MINISAPASO). However, population policy in Rwanda has not lived up to expectations and, as a result, reasonable population projections still lead to quite dramatic increases in the future. It is probably time that the population policy is made effective in order to respond, amongst other concerns, to the growing environmental problems in Rwanda.

8.18 The NES being designed by the Government will produce guidelines for increased environmental protection and better environmental management in the future. Among these guidelines, two aspects will be of particular relevance to the energy sector:

(a) institutional set-up; and

(b) environmental protection tools.

The MINITRAPE will have to liaise with whichever institution will be responsible for environmental protection and management in Rwanda when the environmental strategy recommendations are implemented. It is even possible that MINITRAPE itself should have a small number (one or two) of persons in charge of looking for ways to minimize the environmental impacts of energy development. The best location for such an activity would be with the Planning Unit within the Directorate of Energy.

8.19 The environmental protection tools include the environmental impact assessment procedure, which should be used any time major decisions or investments are to take place. In the energy sector, this is especially the case for forestry exploitation, hydropower development, peat and papyrus exploitation, and large scale methane gas extraction from Lake Kivu. More immediately, and as part of a long-term sustained effort, the Rwandan government should start identifying the training requirements of the staff concerned.

RWANDA - HOUSEHOLD ENERGY CONSUMPTION - 1987

1. Some of the estimates of household energy consumption given in Table 3.1 differs notably from earlier ones. The fuelwood consumption per capita is lower than previously estimated and the proportion of wood used for charcoal is larger. This is due to the following factors:

(a) previous surveys on fuelwood consumption estimates in the rural areas were based on the 1980-82 agricultural survey which yielded very high per capita estimates (0.9 m^3/person/year, or 1.77 kg/person/day), whereas the latest MINIPLAN budget survey produced much lower figures (0.8 kg/person/day). Intermediate figures have been selected for the present estimate;

(b) charcoal consumption for Kigali had been previously estimated at around 15.000 to 20.000 tons/year. A direct survey has produced retail sales of 26.000 tons/year and a household demand estimate showed an overall consumption around 30.000 tons/year, consistent with other observations showing that retailers' sales are inferior to total sales by a substantial margin (underestimating bias by retailers, direct purchases by consumers). Including sales in other towns, the 1987 national consumption is estimated at around 40.000 tons/year. The ESMAP improved stoves project executed a number of charcoal consumption surveys in Kigali and revealed a per capita charcoal consumption of 0.45 to 0.60 kg/day (160 to 170 kg/person/year) for use with traditional stoves. A similar figure was found in Burundi, with a similar type of traditional stove and comparable type of meals. The surveys also showed that charcoal savings due to proper use of improved stoves could amount to over 40% of the monthly charcoal consumption.

2. The use of agricultural residues for cooking has been consistently reported in the various household energy balances produced so far for Rwanda. However, the basis of the estimates produced has never been scientifically sound. One estimate is found in the Energy Assessment for Rwanda from 1982: 170,000 TOE/year, a very high figure when some surveys (e.g., CARE INTERNATIONAL) report that only 15% of rural households use both fuelwood and agricultural residues (the bulk using only fuelwood). The estimate included in the national balance for 1987 (100,000 TOE/year) is 10% of woodfuel consumption.

RWANDA - ENERGY BALANCE: TRADITIONAL FUELS - 1987
(In '000s TOEs)

	Fuelwood	Charcoal	Peat	Papyrus	Agri by-products	Total	Percent
Primary production	1,026.3		0.50	0.00	100.00		
Charcoal conversion	-152.3	30.40					
Consumption							
Households	843.0	30.4	0.1	0.0	100.0	973.5	96.%
Industry	24.0	0.0	0.4	0.0	0.0	24.4	2.4%
Services	7.0	0.0	0.0	0.0	0.0	7.0	0.7%
Total	874.0	30.4	0.5	0.0	100.0	1,004.9	100.0%

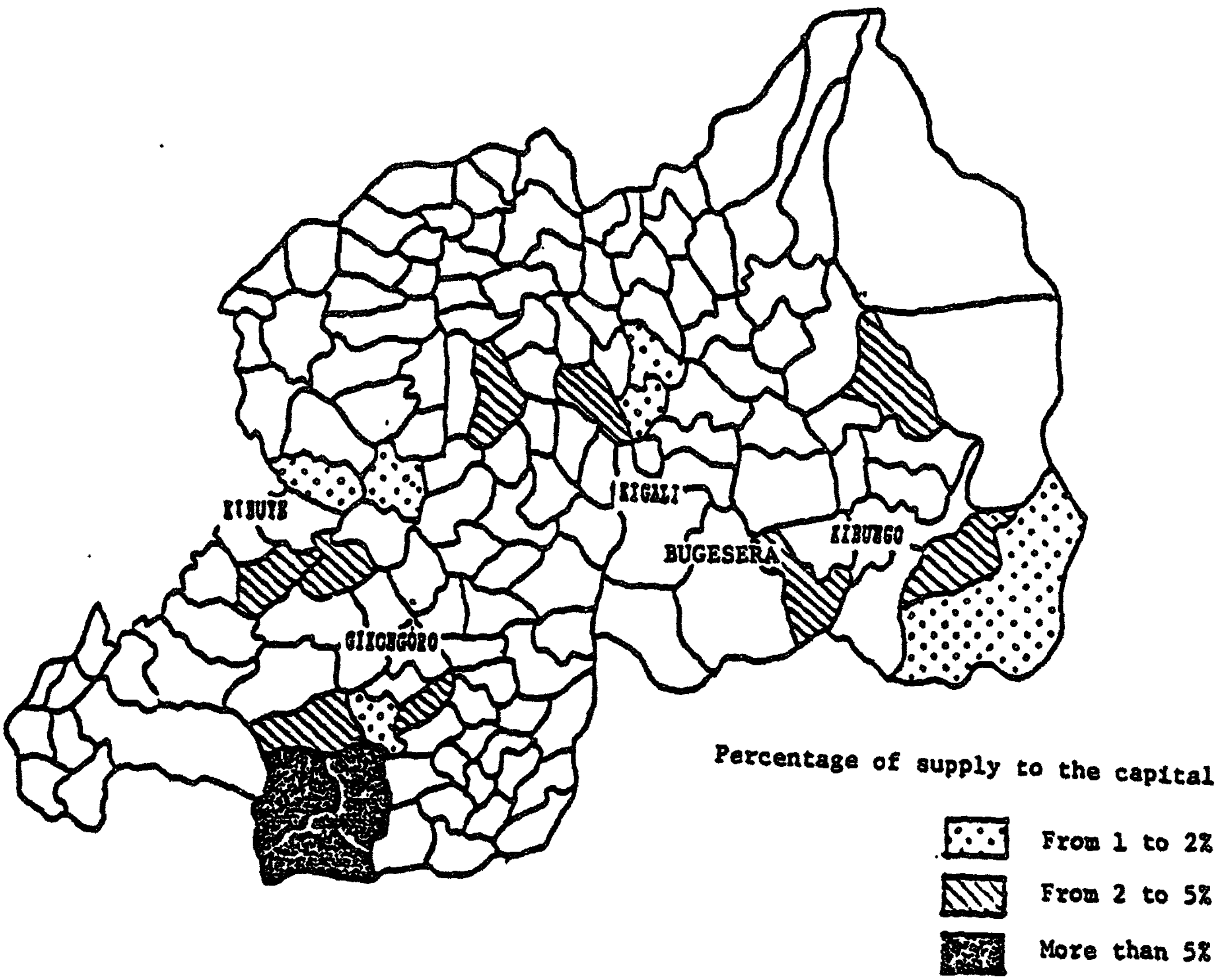
Non-household fuelwood consumption

Tea factories	64,720 stère/year
Sugar factories	3,880 stère/year
Brick factories	30,000 m^3/year
Social centers	22,000 m^3/year
Misc. services	2,000 m^3/year
Bread-making	6,000 m^3/year

Source: Mission estimates; EGL Report 1987; SERETE 1986; BUNEP 1983.

Annex 1.3

DISTRIBUTION OF CHARCOAL PRODUCTION FOR KIGALI MARKET BY PREFECTURE



Source: The "Secteur Charbonnier" Study.

RWANDA - POPULATION PROJECTIONS
(In '000s inhabitants)

Total Population per Prefecture

	1982	1987	1992	1997	2002
Gisenyi	524.0	622.3	728.5	846.6	957.8
Ruhengeri	595.0	706.7	827.2	961.3	1,087.6
Byumba	585.0	694.8	813.3	945.1	1,069.3
Kibuye	377.0	476.6	523.6	608.5	688.5
Gitarama	683.0	811.2	949.6	1,103.5	1,248.5
Kigali	820.0	1,051.5	1,374.3	1,813.3	2,392.4
Kibungo	404.0	479.8	561.7	652.7	738.5
Cyangugu	377.0	476.6	523.6	608.5	688.5
Gikongoro	420.0	498.8	583.9	678.6	767.7
Butare	677.0	804.1	941.2	1,093.8	1,237.5
RWANDA	5,462.0	6,622.0	7,827.0	9,311.8	10,876.3

Urban Population per Town

	1982	1987	1992	1997	2002
Kigali	170.0	269.4	397.4	531.9	711.7
Cyangugu	9.1	11.3	15.1	20.2	27.1
Kibungo	4.7	6.6	8.8	11.8	15.8
Kibuye	3.3	4.7	6.3	8.4	11.3
Ruhengeri	19.5	28.3	37.9	50.7	67.8
Rwamagana	7.4	9.9	13.2	17.6	23.6
Butare	0.0	36.8	49.2	65.9	88.2
Gisenyi	0.0	31.1	41.7	55.8	74.6
Other sec. centers	82.1	59.9	80.3	107.5	143.8
All sec. centers	126.1	188.7	252.5	337.9	452.2
Total urban	296.1	458.1	649.9	869.7	1,163.9
Total rural	5,165.9	6.164.4	7,177.1	8,442.1	9,712.4
Proportion urban	5.4%	6.9%	8.3%	9.3%	10.7%

Source: World Bank and ONAPO.

RWANDA - PROJECTED HOUSEHOLD 1/ ENERGY REQUIREMENTS

SCENARIO I

Physical quantities	1987	1992	1997	2002
Electricity (MWh)	23,821	33,797	45,228	60,525
Kerosene (tons)	8,150	11,563	15,474	20,708
LPG (tons)	237	336	450	602
Agri-by-prod ('000s tons)	300	349	411	473
Fuelwood ('000s tons)	2,213	2,577	3,031	3,487
Charcoal (tons)	40,000	56,752	75,946	101,633
Peat (tons)	500	709	949	1,270
Peat (industry, tons)	1,500	1,905	2,420	3,074
Fuelwood (industry, '000s tons)	63	80	101	128

Tons of Oil Equivalent	1987	1992	1997	2002
Electricity	7,160	10,160	13,396	18,195
Kerosene	8,150	11,563	15,474	20,708
LPG	254	360	482	645
Modern fuels - households	15,564	22,083	29,552	39,548
% of total - households	1.4%	1.6%	1.8%	2.1%
Agri by-products	100,000	116,333	137,000	157,667
Fuelwood	843,048	981,714	1,154,667	1,328,381
Wood used for charcoal	152,381	216,198	289,318	387,173
Peat	143	203	271	363
Traditional fuels - households	1,095,571	1,314,448	1,581,256	1,873,584
Total fuels - households	1,111,136	1,336,531	1,610,808	1,913,132
Peat (Industry)	429	544	691	878
Fuelwood (Industry)	24,000	30,476	38,476	48,762
Traditionalfuels (Industries)	24,429	31,020	39,168	49,640
% of total traditional fuels	2.2%	2.3%	2.4%	2.5%
Total traditional fuels	1,120,000	1,345,469	1,620,424	1,923,224

1/ The use of traditional fuels by other consumer categories is also included for the sake of completeness.

Assumptions:

- In Scenario I, the growth in consumption parallels that of urban population growth for modern fuels, charcoal, and peat (household), and that of rural population growth for fuelwood and agricultural residues.

  The other uses of traditional fuels grow at 4.9% per annum (industrial growth between 1980 and 1985).

Source: Mission estimates.

RWANDA - SUSTAINABLE WOODFUELS SUPPLY - 1987

VOLUME
(In '000s m^3)

Prefecture	Plantations	Arborization	Savannah	Natural	Total Forests
Gisenyi	140.6	189.4	0.5	77.2	407.7
Ruhengeri	178.2	188.9	0.2	30.2	397.5
Byumba	161.2	306.6	46.9	0.0	514.7
Kibuye	99.2	174.3	1.9	10.1	285.6
Gitarama	204.4	288.0	2.4	0.0	494.8
Kigali	141.7	340.3	36.1	10.6	528.8
Kibungo	47.9	300.9	52.4	18.6	419.9
Cyangugu	96.1	165.6	1.8	143.2	406.7
Gikongoro	146.1	229.5	1.2	100.6	477.4
Butare	162.3	238.5	2.2	0.0	403.1
RWANDA	1,377.8	2,422.2	145.7	390.6	4,336.2
	31.8%	55.9%	3.4%	9,0%	100.0%

WEIGHT
(In '000s tons)

Prefecture	Plantation	Arborization	Savannah	Natural Forest	Total	Surplus/-Deficit 1/	Percentage of Demand
Gisenyi	84.3	113.6	0.3	46.3	244.6	34.1	16.2
Ruhengeri	106.9	113.4	0.1	18.1	238.5	-216.9	-47.6
Byumba	96.7	183.9	28.1	0.0	308.8	105.9	52.2
Kibuye	59.5	104.6	1.2	6.1	171.3	32.2	23.1
Gitarama	122.6	172.8	1.5	0.0	296.9	60.0	25.3
Kigali	85.0	204.2	21.7	6.4	317.3	-238.9	-43.0
Kibungo	28.8	180.6	31.5	11.2	251.9	111.8	79.8
Cyangugu	57.7	99.4	1.1	85.9	244.0	104.9	75.4
Gikongoro	87.7	137.7	0.7	60.4	286.4	-23.1	-7.5
Butare	97.4	143.1	1.3	0.0	241.9	-26.9	-10.0
RWANDA	826.7	1,453.3	87.4	234.3	2,601.7	-505.8	-16.3

Assumptions: (Tree productivity and area).

- Arborisation: 7.5% of agricultural land; 20.0 m^3/ha/year.
- Plantations: 9.0 m^3/ha/year.
- Savannah: 1.0 m^3/ha/year.
- Natural forests: 3.0 m^3/ha/year (actual); 0.0 m^3/ha/year (authorized).

1/ The overall deficit has been assessed by adding up all regional deficits, the assumption being that little or no interregional trade takes place. This is not entirely true as Gikongoro, for instance, supplies Kigali with charcoal. If the statistics are correct Gikongoro prefecture experiences a deficit notably larger than the one presently identified, the difference being woodfuels supplied to Kigali.

Source: "Secteur Charbonnier" study; mission estimates.

RWANDA - WOODFUELS BALANCE - 2002

AREA INCREASES UNTIL 2002
(In '000s hectares)

Year	Plantations	Arborization	Savannah	Natural Forests	Total
1988	7.0	13.0	-4.6		15.4
1989	7.0	13.0	-4.6		15.4
1990	7.0	13.0	-3.4		16.6
1991	7.0	13.0		1.5	21.5
1992	7.0	13.0		1.5	21.5
1993	7.0	13.0		1.5	21.5
1994	7.0	13.0		3.0	23.0
1995	7.0	13.0		3.0	23.0
1996	7.0	13.0		3.0	23.0
1997	1.1	11.5		5.4	18.0
1998				5.4	5.4
1999				5.4	5.4
2000				5.4	5.4
2001				5.4	5.4
2002				5.4	5.4

SUSTAINABLE SUPPLY OF WOODFUELS - 2002
(In '000 tons)

Prefecture	Plantation	Arborization	Savannah	Natural Forest	Total	Surplus/-Deficit 1/	Percentage
Gisenyi	119.7	223.1	0.3	92.1	445.2	96.5	27.7
Ruhengeri	151.7	232.5	0.1	36.0	420.3	-295.0	-41.2
Byumba	137.2	377.3	27.2	0.0	541.7	229.5	73.5
Kibuye	84.5	214.5	1.1	12.0	312.2	111.1	55.3
Gitarama	174.0	354.5	1.4	0.0	529.9	165.3	45.3
Kigali	120.7	418.8	20.9	12.7	573.1	-783.6	-57.8
Kibungo	40.8	370.4	30.4	22.2	463.7	248.1	115.0
Cyangugu	81.8	203.9	1.0	170.7	457.4	256.4	127.6
Gikongoro	124.4	282.4	0.7	120.0	527.5	51.1	10.7
Butare	138.2	293.6	1.3	0.0	433.1	- 9.8	- 2.2
RWANDA	1,172.8	2,981.0	84.4	465.7	4,704.0	-1,088.4	-18.8

Assumptions:

- Area increases until year 2002 in accordance with "Plan Forestier National".
- Area increases are assigned to each particular prefecture in proportion to intial areas.
- Logging of natural forests produces 150 m^3/ha.
- Sustainable productivities remain as in 1987.

1/ The overall deficit has been assessed by adding up all regional deficits, the assumption being that little or no interergional trade takes place. This is not entirely true as Gikongoro, for instance, supplies Kigali with charcoal. If the statistics are correct Gikongoro prefecture experiences a deficit notably larger than the one presently identified, the difference being woodfuels supplied to Kigali.

Source: "Plan Forestier National"; mission estimates.

SENSITIVITY ANALYSIS OF PLAN FORESTIER NATIONAL

Percentage achievement of plantation program compared to target	Resulting woodfuel deficit in 2002 ('000s tons)
100	-1,088
80	-1,209
60	-1,352
40	40
40	-1,509
120	- 996

Source: "Plan Forestier National"; mission estimates.

RWANDA - PRESENT VALUE COSTS OF PLANTATION FOR PRIVATE AND PUBLIC OWNERS (1987)

Annual yield (m^3/ha)	State plantation			Communal plantation			Private plantation			
	8	12	14	8	12	14	8	12	18	24
Costs (RF '000s/ha)										
Total costs	128.7	128.7	128.7	32.6	32.6	32.6	40.0	40.0	40.0	40.0
of which planting	76.5	76.5	76.5	18.7	18.7	18.7	15.4	15.4	15.4	15.4
Production over 25 years										
Total m^3 yield	202	303	354	202	303	354	200	300	450	600
Total stères	303	455	530	303	455	530	300	450	675	900
Production cost of standing wood										
RF/m^3	2,972	1,981	1,669	754	503	431	726	482	322	241
RF/stère	1,981	1,321	1,113	503	335	287	484	321	215	161

Assumptions: Discount rate 10%.

Note: The high costs for Government plantations are due to labor costs and large overheads.

Source: The "Secteur Charbonnier" study, and other data from individual plantations with different ownership.

RWANDA - PRICES FOR FUELWOOD 1/ PROPOSED BY DGF

Location	Tree categories 1	Tree categories 2	Tree categories 1	Tree categories 2
	--- Standing ---		Felled and piled	
RF/stère:				
Kigali	600	300	700	400
Gikongoro	400	200	500	300
Cyangugu	400	200	500	300
Kibuye	350	150	450	250
Others	450	250	550	350
RF/kg:				
Kigali	1.54	0.77	1.79	1.03
Gikongoro	1.03	0.51	1.28	0.77
Cyangugu	1.03	0.51	1.28	0.77
Kibuye	0.90	0.38	1.15	0.64
Others	1.15	0.64	1.41	0.90

Assumptions:

- Stère = 0.65 m^3.
- Density = 600 kg/m^3.
- Category "1 trees": Grevillea robusta, Eucalyptus spp, Acacia spp, "Savannah wood"; Category "2 trees": Pinus spp, Callitris spp, Deciduous spp from natural mountain forests

1/ Present stumpage fee: RF 400/stère.

Source: DGF: "Proposal For New Wood Prices".

RWANDA - CHARCOAL PRICE STRUCTURE

	RF/bag	RF/kg	US$/ton
Kigali selling price	550	15.3	204.00
Retailer margin	100	2.8	37.30
Transportation	130	3.6	48.00
Charcoaler labor	243	6.8	90.70
Standing wood price	77	2.10	28.00

Monthly labor value: RF 7,290/charcoaler/month = US$97.00

Assumptions:

- Transport cost: RF 1.3/bag/km
- Distance transportation: 100 km
- Unit bag weight: 36 kg
- Carbonization efficiency: 12.0%
- Standing wood price: RF 100/stère

Stère volume: 0.65 m^3 per stère
Density: 600 kg/m^3
Productivity: 30 bags per charcoaler per month

MONTHLY LABOR VALUE ACCORDING TO STANDING WOOD PRICE

Standing wood price per stère (RF)	Monthly charcoaler labor value RF	US$
0	9,600	128
100	7,290	97
200	4,985	66
300	2,677	36
400	369	5
500	-1,938	-25

Source: The "Secteur Charbonnier" study; mission estimates.

RWANDA - COMPARATIVE INCOMES FROM TRADITIONAL AND IMPROVED CARBONIZATION

	Traditional			Improved		
	RF/bag	RF/kg	US$/ton	RF/bag	RF/kg	US$/ton
Kigali selling price	550	15.30	204.00	550	15.30	204.00
Retailer margin	100	2.80	37.30	100	2.80	37.30
Transportation	130	3.60	48.00	130	3.60	48.00
Charcoal tax	60	1.70	22.70	30	0.85	11.30
Charcoaler labor	183	5.10	68.00	239	6.60	88.00
Standing wood price	77	2.10	28.00	46	1.30	17.30
Investment depreciation	0	0.00	0.00	5	0.10	1.90
Monthly labor value	RF 5,490 = US$ 73.00			RF 7,170 = US$ 96.00		

Assumptions: See Annex 3.11.
- Improved carbonization efficiency: 20%
- Improved carbonization investment: RF 5,000/charcoaler.
- Life duration of investment: 2 years.
- Improved carbonization production: 500 bags/charcoaler/year.

INFLUENCE OF TRANSPORTATION DISTANCE AND STANDING WOOD PRICE ON CHARCOALER LABOR VALUE

Traditional method	Distance in kilometers				
Wood price	0	50	100	150	200
	RF				
0	11,700	9,750	7,800	5,850	3,900
100	9,392	7,442	5,490	3,542	1,592
200	7,085	5,135	3,185	1,235	-715
300	4,777	2,827	877	-1,073	-3,023
400	2,469	519	-1,431	-3,381	-5,331
Improved methods	0	50	100	150	200
	RF				
0	12,450	10,500	8,550	6,600	4,650
100	11,065	9,115	7,170	5,215	3,265
200	9,681	7,731	5,781	3,831	1,881
300	8,296	6,346	4,396	2,446	496
400	6,912	4,962	3,012	1,062	-888

Notes:
- As can be seen the direct impact of the charcoal tax will be to significantly reduce traditional charcoaler's income.
- Another important factor in price build-up is the standing wood value. Making the official price mandatory will greatly reduce the traditional charcoaler's income. Only the improved method will allow a reasonable income to be generated at the official standing wood price (RF 400/stère).

Source: The "Secteur Charbonnier" study; mission estimates.

RWANDA - BIOMASS ENERGY-RELATED PROJECTS

Project name	Start	End	Financing	Government
Fuelwood conservation	1986	1989	Netherlands	DGE/MINITRAPE
Improved Charcoal Stoves & Kilns	1987	1989	UNPD/Netherlands	DGE/MINITRAPE
Reforestation	1985	1989	Belgium	MINAGRI
Municipal Agro-Forestry	1983	1987	USAID	MINAGRI
Gituza Forestry	1984	1988	USAID	MINAGRI
Pilot Forestry	1986	1987	CTS	MINAGRI
Management Unit I	1986	1990	CTS	MINAGRI
Support to DGF	1986	1990	CTS	MINAGRI
Muhura Agro-forestry	1986	1987	Finland	MINAGRI
Forestry I	1981	1987	IDA	MINAGRI
Forestry II	1988	1993	IDA	MINAGRI
Rural Development (Zaire-Nile)	n/a	n/a	FED	MINAGRI
Nyungwe Forestry	1987	1989	CCCE	MINAGRI
Biogaz	1987	1989	GTZ	MINITRAPE
Pilot Production Peat	n/a	n/a	Ireland	MINITRAPE

Source: DGF.

WOODFUEL CONSERVATION MEASURES

Improved Charcoal Stoves

1. The RONDEREZA 1/ stove is developed by the World Bank and the United Nations Development Programme (UNDP) which in parallel have embarked upon a more systematic program to test and gradually disseminate socially acceptable models. The test has started with 120 families from various neighborhoods in Kigali. Each family participated for three months using one of the three models for a period of one month, and eventually selecting as a gift the preferred one. Two stove designs were based on the recommendations of a previous World Bank mission (known as KIGALI HAUT and KIGALI BAS), the third one being the CANAMAKE stove. As a result of this first test phase, the preferred model was the KIGALI HAUT (renamed by the households: RONDEREZA), followed by KIGALI BAS, the CANAMAKE model coming last, partly on account of the poor quality of the stoves handed over to the project. A second phase of the project includes demonstration of 1,000 stoves (among 500 families), a publicity/marketing campaign and recommendations for a large scale dissemination scheme. At this stage, it is too early to make an assessment of the operation of this project.

2. During a next phase of the project, actual efficiency of the improved stoves will be tested in conditions as close as possible to real life. Until now, laboratory experiments have produced encouraging results: CANAMAKE and KIGALI HAUT consumed respectively 28% and 39% less charcoal than the traditional IMBABURA. The return on investment on the RONDEREZA stove could indeed be very attractive if its performances are confirmed: households originally consuming three bags of charcoal/month would save about 1 bag of charcoal/month if RONDEREZA saves 35% of fuel. Under present market conditions, this would mean savings of the order of RF 550/month, more than enough to compensate for the initial price difference between traditional IMBABURA (RF 150) and RONDEREZA (about RF 400 at present).

3. The tests among the 500 families has almost been completed and initial evaluation shows that the overwhelming majority of households likes the RONDEREZA very much. Certain technical aspects require further improvements, however, and this is being looked into by a Rwandan metal work specialist before the large-scale dissemination and advertisement campaign starts. The advertisement campaign will address the urban population to commence energy saving measures. It will specifically mention the use of the RONDEREZA and the CANAMAKE stoves. It is anticipated that the two stoves will not compete with one another but complement each other as they are intended for different market segments.

1/ *RONDEREZA means in Kinyarwanda: "He who saves". The stove costs approximately RF 400. A traditional stove is sold for roughly RF 250.*

Improved Carbonization Techniques

4. Improved carbonization techniques have been investigated by a Rwandan team with assistance from foreign consultants under the ESMAP program. The project trains traditional charcoalers at the sites where they normally produce their charcoal. So far, some 130 charcoalers have been trained and it is expected that a total of 250 charcoalers will have been trained by the end of 1989. More importantly, project personnel have estimated that 60% of all trained charcoalers continued to use the improved method and that they have trained other charcoalers in the use of this method. It was observed that in certain villages, charcoalers started to form groups in which they now work. This movement is strongly supported by the project, and a new association of professional charcoalers is proposed. The association will provide information among groups of charcoalers on techniques, availability of wood, and will try to obtain financing to improve their operations. The groups that use improved techniques are experimenting earnings that are 2 to 4 times higher than when the charcoalers worked alone.

5. The improved charcoalization method introduced was the CASAMANCE method, an "improved traditional" method. During the course of the work, the kiln was slightly modified (adapted to the terrain in Southwest Rwanda). The two major differenes betwen the traditional and the improved method are of operational and technical nature: wood drying and wood stacking during the preparatory phase as well as closely following the kiln's performance during the carbonization phase are operational improvements which, in this case applied to the traditional method, would also improve its performance. Technical improvements are obtained by reversing the draft of hot gases through application of a metal chimney (made of used oil-barrels). These two types of improvements result in a charcoal of more even quality, a higher output of charcoal, and a quicker carbonization process.

6. Field results as executed under the improved charcoal production project show that the traditional carbonization technique has an overall (dry weigth) efficiency of roughly 7-9%. The performance of the traditional kiln was measured during 50 trials, all the work was done by traditional charcoalers and monitored by the Rwandan counterpart team. The following table gives an overview of the results:

PERFORMANCE TRADITIONAL KILN

	Smallest	Average	Largest
Size of kiln (in stères)	1.3	6.8	15.2
Moisture content (in % m.c.w.b.a/)	29	29	29
Total duration (in days)	1.6	5.4	11
Carbonization time (in days)	0.9	5.3	8
Output (in kgs)	35	255	928
Efficiency	5.7%	8%	13%

a/ % m.c.w.b. = Percentage moisture content wet basis.

Source: ESMAP/MINAGRI.

7. Reasons for such a low efficiency are the high moisture content of the wood (charcoalers cut the wood and carbonize it right away; moisture content is often 35% m.c.w.b. or higher); minimal or no supervision takes place during the carbonization process. Moreover, charcoal making is a technique which was fairly recently introduced in Rwanda, hence, traditional skills are not very widespread.

8. Results of the improved method, under field conditions, show that the average efficiency (dry weigth) amounts to 18%, an improvement of 60%. Some 100 trials with Eucalypts wood were monitored during the first four months of the field work; work was done by traditional charcoalers who were trained and monitored by the Rwandan counterpart team. The following table gives an overview of the results.

PERFORMANCE IMPROVED CHARCOAL KILN (MEULE CASAMANCAISE

	Smallest	Average	Largest
Size of kiln (in stères)	10	14.8	30
Moisture content (in % m.c.w.b.)	25	30	30
Carbonization time (in days)	1.7	3.6	6.9
Efficiency	15%	18%	26%

Source: ESMAP/MINAGRI.

RWANDA - FINANCIAL AND ECONOMIC COST COMPARISONS OF HOUSEHOLD FUELS

	Economic a/			Financial a/		
	Charcoal	Kerosene	LPG	Charcoal	Kerosene	LPG
Unit	kg	liter	kg	kg	liter	kg
Consumer prices (RF)	15	57.4	137	15	60.5 b/	165
Calorific value (MJ)	30	35	45	30	35	45
Stove efficiency (%)	19	40	40	19	40	40
Cost per useful MJ (RF)	2.6	4.1	7.6	2.6	4.3	9.2

	Financial		
	Charcoal	Papyrus briquettes	Peat
Unit	kg	kg	kg
Consumer prices (RF)	15	8 c/	8
Calorific value (MJ)	30	17	12
Stove efficiency (%)	19	17	12
Cost per useful MJ (RF)	2.6	2.8	5.6

Notes: The lack of precise cost data do not, at this stage, permit the distinction between economic and financial values for all the fuels.

a/ The difference between economic and financial prices for kerosene and LPG is made up of local taxes and import duties.

b/ The higher price for kerosene, here compared to Annex 2.6, is explained by distribution costs and sales in small quantities at household level.

c/ Actual selling price (promotional) is RF 4/kg, as compared to an estimated, more realistic, price based on total costs of RF 8 (see Annex 1.15).

Source: The "Secteur Charbonnier" study; mission estimates.

PAPYRUS BRIQUETTES

The Resource

1. The resource potential has been investigated and it was estimated that, without being as plentiful as in other East African countries (e.g., 300,000 ha of papyrus swamps in Uganda), sizeable quantities could be drawn from Rwandan "marais".

2. Experts usually recognize that as much as 16 tons/ha (air dried) could be harvested every two years without damage to the environment. This harvest could last for about eight months and mainly depends upon the rainy season. Detailed USAID and Irish-financed studies showed that 23,000 ha of papyrus swamps are available in Rwanda, with the following distribution:

Within 20 km of Kigali	2,000 ha
Within 40 km of Kigali	5,000 ha
Along rivers, west of the lake region and south to the border to Burundi	16,000 ha
Total in Rwanda	23,000 ha

Processing

3. The present pilot capacity is 2 t/day of 8 hours, and could be increased to 4 tons. The machinery used is apparently state-of-the-art, though a lot of manual labor is still requiried. The pilot factory is presently under the supervision of an expatriate expert.

Marketing

4. Marketing has started under the guidance of MINITRAPEE. The briquettes sell at RF 4/kg in bags of 50 kg (charcoal approx. RF 15/kg) which is only approximately 60% of the estimated costs (see below). The calorific value is estimated at 17 MJ/kg of briquette.

Costs

5. They were tentatively estimated on the basis of a visit to the pilot plant. In the marais, 14 laborers cut the papyrus; one truck hauls it over 12 km (cost per ton/km can be estimated at RF 40 for dense material); and 10 laborers, including 2 qualified, do the processing. However, since 6,000 ha are located less than 30 km from Kigali, an average transport distance of 20 km is considered in the following simplified analysis:

<u>Labor cost</u>
22 x RF 150 + 2 x RF 300 = RF 3,900/day

<u>Electric power cost</u>
10 kW x 8 = 80 kWh x RF 8.5/kWh = RF 680/day

<u>Transportation cost</u>
RF 1,600/t (especially if returning empty)

<u>Investment costs and depreciation rate</u>
Equipment costs: \$30,000
freight and insurance: \$15,000
Annual maintenance costs: 10% of equipment costs
Operational: 50% of year
Lifetime of equipment: 5 years
30,000/5 + 15,000/5 + 3000 = \$12,000 per year
which is equivalent to RF 5,260/day, or RF 2,630/t

<u>Estimated costs</u>
based on 2 tons/day production
RF 4,580/2 + RF 1,600 + RF 2,630= RF 6,520/t

6. The actual cost could thus possibly be in the range of RF 8/kg to RF 10/kg (including overhead and profit margin) which would compare with charcoal at present market prices, at least if production could be increased as indicated above. A detailed economic analysis should be conducted and this should be linked with a market study before any decisions are made to further increasing investments in briquetting.

7. In 1987, production was 52 tons, much too small for economically viable operations. At an "optimum" size of 30 tons/day, GORDON MELVIN & PARTNERS estimate that total cost would be around US\$2/GJ (that is RF 2.7/kg), which seems very optimistic.

<u>Utilization</u>

8. Utilization problems are reported, e.g., smoke and difficulties in lighting and the diameter of the briquette is large, which probably does not facilitate ignition and which requires cutting of the briquette before loading into a stove in case it is used for cooking. The moisture content of the briquette was not assessed, but might create problems.

<u>Further Development</u>

9. MINAGRI's Direction du Génie Rural is preparing a global inventory of "marais" in Rwanda. They have initiated a pilot project in three communes: Mbogo, Tare (both of the Kigali prefecture), and Tumba (of the Byumba prefecture) with some help from USAID. They are currently approaching the UNDP to obtain financing for the large scale inventory.

RWANDA - UTILIZATION OF PEAT AS A FUEL

The following drawbacks and obstacles to commercial development have been observed:

- peat resources are located at some distance from the main center of consumption, Kigali, and are not accessible by tar roads. Transportation of peat bags is very costly and reduces the competitiveness of peat versus charcoal. The latter can be produced from a variety of places, all close to paved roads;

- at places where peat is produced and that were visited by the mission, there were signs of poor handling of the resource: due to defective storage conditions, peat blocks had returned to their original diluted state making them impossible to transport and use. There is a considerable risk that this may prove to be a recurrent problem;

- in spite of very limited direct evidence, the economics of peat exploitation for household energy supply do not appear attractive under any scenario. The main resources are located at least 80 km of Kigali on very bad dirt roads. The cost of transportation alone will be at least

  RF 50 x 80 = RF 4,000/ton delivered Kigali

  Labor cost for exploitation is at least RF 1,000/t (based on the estimate: 300 man-months minimum for a production of 740 tons) excluding depreciation on machinery and overhead. The calorific value of peat is around 12 MJ/kg. Altogether, the cost per useful MJ would be more than twice that of charcoal at present prices, with little hope for any substantial savings in the peat production/transportation line;

- according to the long experience with peat in Burundi, peat can hardly be considered as a household cooking fuel, and this also holds in a practical Rwandan setting: it has a low calorific value, burns very slowly, leaves a considerable quantity of ashes behind (30% ash content), smells and fumes, and would, by no standards, compete with charcoal in use. However, if production, transport and distribution is properly organized, peat might become an alternative for petroleum fuels or electricity in commercial activities, but detailed feasibility studies need to be carried out first; and

- the environmental impacts of peat extraction have not been seriously looked into so far. Experience from other countries suggest that the environmental impact could be very damaging if exploitation is not properly planned and managed.

RWANDA - PROJECTED HOUSEHOLD 1/ ENERGY REQUIREMENTS - SCENARIO II

Physical quantities	1987	1992	1997	2002
Electricity (MWh)	23,821	33,797	45,228	60,525
Kerosene (tons)	8,150	11,563	15,474	20,708
LPG (tons)	237	336	450	602
Agri by-prod. ('000s tons)	300	349	411	473
Fuelwood ('000s tons)	2,213	2,577	2,974	3,293
Charcoal (tons)	40,000	56,752	70,749	82,643
Peat (tons)	500	709	949	1,270
Papyrus Briquettes (tons)	0	0	3,750	7,500
Peat (industry, tons)	1,500	1,905	2,420	3,074
Fuelwood (industry, '000s tons)	63	80	101	128

TOE	1987	1992	1997	2002
Electricity	7,160	10,160	13,596	18,195
Kerosene	8,150	11,563	15,474	20,708
LPG	254	360	482	645
Modern fuels - households	15,564	22,083	29,552	39,548
% of total - households	1.4%	1.6%	1.9%	2.2%
Agri by-products	100,000	116,333	137,000	157,667
Fuelwood	843,048	981,714	1,132,952	1,254,476
Wood used for charcoal	152,381	216,198	269,520	314,830
Peat	143	203	271	363
Papyrus briquettes	0	0	1,587	3,175
Traditional fuels - households	1,095,571	1,314,448	1,541,331	1,730,511
Total fuels - households	1,111,136	1,336,531	1,570,883	1,770,059
Peat (industry)	429	544	691	878
Fuelwood (industry)	24,000	30,476	38,476	48,762
Traditional fuels - industries	24,429	31,020	39,168	49,640
% of total - traditional fuels	2.2%	2.3%	2.4%	2.7%
Total traditional fuels	1,120,000	1,345,469	1,580,498	1,780,151

IMPACT ON WOODFUELS CONSUMPTION

TOE	1987	1992	1997	2002
Scenario I	1,019,428	1,228,389	1,482,462	1,764,316
Scenario II	1,019,428	1,228,389	1,440,948	1,618,068
Percentage change from Scenario I to II	0.0%	0.0	-2.8%	8.3%

1/ The use of traditional fuels by other consumer categories is also included for the sake of completeness.

Assumptions:

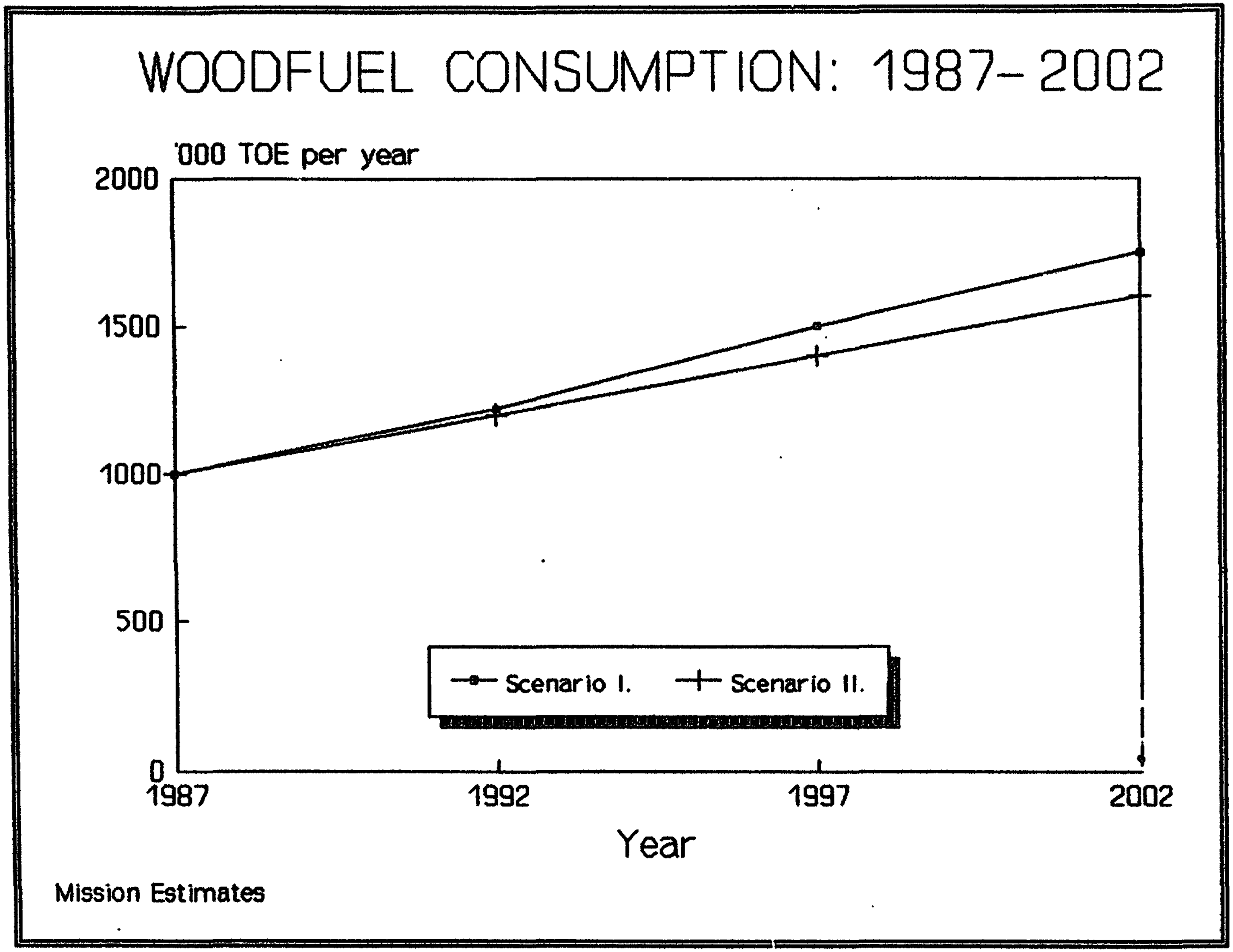
In Scenario II assumptions compared to Scenario I are as follows:

- Papyrus briquettes are developed to the equivalent of 500 ha at 15 tons per ha/year by year 2002. Each ton of papyrus saves 0.5 ton of charcoal.
- 10% of charcoalers use improved carbonization methods by year 2002. -25% of urban households use improved charcoal stoves by 2002, saving 35% on consumption.
- 15% of rural households use improved cooking methods that reduce end-use consumption by 25% in 2002.
- Utilization of other energy sources is unaffected.
- Half of the above achievements are assumed to be reached by year 1997.

Source: Mission estimates.

Annex 1.18

WOODFUELS CONSUMPTION - 1987-2002
(Thousand TOEs/year)



RWANDA: CONSUMPTION OF PETROLEUM PRODUCTS
(Tons)

	1983	1984	1985	1986	1987	Change p.a. (%) 1983-87
Imports						
Aviation gasoline	376	263	299	393	465	5.5
Automobile gasoline	34,188	33,298	35,486	38,716	37,240	2.2 a/
Kerosene	2,134	3,332	4,672	7,370	8,7754	2.4
Jet JP 1	3,846	6,333	5,539	4,662	4,744	5.4
Diesel	22,941	26,997	31,814	35,008	27,329	4.5 a/
Fuel oil	2,319	2,358	2,393	3,881	11,3434	8.7
LPG	196	202	198	235	237	6.9
Total	66,000	72,783	80,401	90,265	90,133	8.1
Contraband products	-	-	-	1,200	12,000	n.a.
Total consumption	66,000	72,783	80,401	91,465	102,133	1.5

a/ The clandestine imports consist mainly of diesel and some automobile gasoline.

Sources:

- Imports: Direction du Commerce Extérieur. Banque Nationale du Rwanda.
- Contraband products: Mission estimate.

RWANDA: STRUCTURE OF PETROLEUM PRICES
(Average annual figures, 1983-87)
(RF/kg)

	FOB price 1/	Trans-portn.	CIF Kigali	Import duties 2/
AUTO GASOLINE				
1983	44.04	21.05	65.09	-
1984	40.72	20.91	61.63	-
1985	36.91	20.70	57.61	17.39
1986	24.79	20.56	45.35	17.18
1987	20.29	20.07	40.46	12.50
KEROSENE				
1983	40.84	15.78	56.62	0
1984	39.72	17.26	56.98	0
1985	34.29	16.16	50.45	0
1986	27.78	20.67	48.45	0
1987	23.00	19.51	42.51	0
DIESEL				
1983	34.81	19.22	54.03	-
1984	34.78	18.45	53.23	-
1985	31.47	17.92	49.39	11.98
1986	22.65	17.73	40.39	11.38
1987	17.47	16.68	34.15	6.22
FUEL OIL				
1983	18.60	15.85	34.45	-
1984	18.23	15.67	33.90	-
1985	17.41	15.83	33.25	3.00
1986	11.53	14.90	26.42	3.00
1987	9.62	15.61	25.23	1.26
LPG				
1983	54.40	37.66	92.06	-
1984	55.69	54.88	110.57	-
1985	49.15	51.23	100.38	24.58
1986	32.95	46.73	79.68	20.80
1987	27.96	51.46	79.42	19.81

1/ FOB Nairobi for 80% of imports. Remainder FOB-Mombasa, Dar es Salaam, Gulf, Djibouti, and so on.

2/ Duties actually collected, taking into account certain exemptions. The latter became important in 1987.

Source: Banque Nationale du Rwanda for the basic data.

EVOLUTION OF STRUCTURE OF PETROLEUM PRICES
(Examples)
(RF/m3)

	February 86		November 86		May 87		March 88		June 88	
Exchange rate RF/US$	89		86		80		77		75	
	Gaso-line	Diesel	Gaso-line	Diesel	Gaso-line	Diesel	Gaso-line	Diesel	Gaso-line	Diesel
CIF-Mombasa, RF/m³			10,853		14,068					
Transfer port of Mombasa (1%)			109		140					
Pipeline Mombasa-Nairobi			3,220		2,720					
CIF-Nairobi	25,050	24,490	14,182	13,418	16,928	16,126	13,710	13,440	13,240	11,845
Transfer Nairobi-Kigali	14,500	14,500	14,500	14,500	14,500	14,500	14,500	14,500	14,500	14,500
Insurance (1%)	399	394	290	282	317	309	285	282	280	266
CIF-Kigali	39,949	39,384	28,972	28,200	31,745	30,935	28,495	28,222	28,020	26,611
Import duties	13,230	12,600	13,230	12,600	13,230	12,600	17,640	17,640	17,640	17,640
Magerwa tax (4%)	1,598	1,575	1,159	1,128	1,270	1,237	1,140	1,129	1,121	1,064
Turnover tax (6%)	-	-	2,602	2,516	2,775	2,686	2,837	2,819	2,807	2,719
Road Fund Tax	-	-	8,000	8,000	11,000	11,000	11,000	11,000	8,000	8,006
Subtotal: Taxation	14,828	14,175	24,991	24,244	28,275	27,523	32,617	32,588	29,568	29,421
Expenses + wholesale margin	9,623	7,941	10,437	9,056	4,380	3,042	3,288	690	6,812	5,466
Retail margin	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Retail selling price	66,800	63,900	66,800	63,900	66,800	63,900	66,800	63,900	66,800	63,900

Source: Mission estimates based on data from oil companies.

RWANDA: HISTORY OF PETROLEUM PRICE REGULATION

	Auto Gasoline	Diesel fuel
November 21, 1981		
Order No. 06/13.01/81, setting maximum fuel prices:		
- Wholesale price, Kigali: RF/lit	64.40	61.50
- Retail margin: RF/lit	2.40	2.40
- Retail price at pump: RF/l	66.80	63.90
Of which: Import duties RF/kg	6	4
NAGERWA tax, RF/truck	1,000	1,000
April 30, 1984		
Law No. 11/11/84, raising import duty from RF 6 to 18 and RF 4 to 15/kg	18	18
January 2, 1986		
Order No. 00 /FIN.7.08, altering the NAGERWA tax from RF 1,000/truck to 4% of value CIF-Kigali	4%	4%
March 24, 1986		
Order No. 002/07/ECO/86, creating the Roads Fund, RF/liter	8	8
April 1, 1986		
Law No. 1/86, creating the Turnover Tax: 6% of value CIF-Kigali plus import duty and NAGERWA tax	6%	6%
May 20, 1987		
Order No. 03/ECO/87, increasing the Road Fund from RF 8 to RF 11/liter	11	11
March 3, 1988		
Law No. 10/88, raising import duty from RF 18 to 24 and RF 15 to 21/kg	24	21
March 16, 1988		
Ministerial Order reducing the Road Fund from RF 11 to 8/liter	8	8

Source: Bulletin Officiel.

RWANDA: TAXES AND CHARGES ON PETROLEUM PRODUCTS
(June 1988)

	Import duties	MAGERWA tax 1/	Turnover tax 2/	Road Fund
Aviation gasoline	RF 9/kg	4%	6%	--
Automobile gasoline	RF 24/kg	4%	6%	RF 8/lit
Kerosene	--	4%	6%	--
Diesel	RF 21/kg	4%	6%	RF 8/lit
Fuel oil	RF 3/kg	4%	6%	--
LPG	25%	4%	6%	--

1/ 4% on CIF-Kigali, comprising MAGERWA remuneration 1% and 3% for the Development Budget managed by the Ministry of Finance.

2/ 6% on the price after customs clearance (CIF + import duties + MAGERWA tax).

Source: Banque Nationale du Rwanda; Bulletin Officiel.

RWANDA: STRUCTURE OF PETROLEUM PRICES, JUNE 1988
(RF/m3 and, for LPG, RF/ton)

	Aviation gasoline	Autom. gasol.	Kerosene	Diesel	Fuel oil	LPG
CIF-Kigali	50,000	28,020	30,600	26,611	22,500	80,000
Taxation						
Import duties	6,660	17,640	-	17,640	2,790	20,000
Magerwa tax (4%)	2,000	1,121	1,224	1,064	900	3,200
Turnover tax (6%)	3,520	2,807	1,909	2,719	1,571	6,192
Road Fund tax	-	8,000	-	8,000	-	-
Subtotal, Taxation	12,180	29,568	3,133	29,423	5,261	29,392
Wholesale expenses and margin	10,000	6,812	13,867	5,466	8,239	50,608
Retail margin	-	2,400	2,400	2,400	-	5,000
Total, maximum selling price	72,180	66,800	50,000	63,900	36,000	165,000

Note: Only automobile gasoline and diesel prices are controlled.

Source: Mission estimates, based on figures from oil companies.

RWANDA - PROJECTED CONSUMPTION OF ELECTRICITY
(GWh)

	Scenario A				Scenario B				Scenario C			
	Industrial	Public Serv.	Resid./Comm.	Total	Industrial	Public Serv.	Resid./Comm.	Total	Industrial	Public Serv.	Resid./Comm.	Total
1987	36.5	30.1	38.6	105.2	36.5	30.1	38.6	105.2	36.5	30.1	38.6	105.2
1988	37.6	31.6	40.4	109.6	37.6	31.6	42.2	111.4	38.3	32.2	43.0	113.5
1989	38.7	33.2	42.0	113.9	38.7	33.2	45.9	117.8	40.2	34.5	49.5	124.2
1990	39.9	34.9	44.0	119.2	39.9	34.9	50.8	125.6	42.2	36.9	56.9	136.0
1991	41.1	36.6	48.9	126.6	41.1	36.6	58.4	136.1	44.4	39.5	65.4	149.3
1992	42.3	38.5	53.8	134.6	42.3	38.5	67.1	147.9	46.6	42.3	75.2	164.1
1993	43.6	40.4	59.1	143.1	43.6	40.4	77.2	161.2	48.9	45.2	86.5	180.6
1994	44.9	42.4	65.1	152.4	44.9	42.4	88.8	176.1	51.4	48.4	99.5	199.3
1995	46.2	44.5	71.6	162.3	47.2	44.5	102.1	192.8	53.9	51.8	114.4	220.1
1996	47.6	46.7	78.7	173.0	47.6	46.7	117.5	221.8	56.6	55.4	131.6	243.6
1997	49.0	49.1	86.6	184.7	49.0	49.1	135.1	233.2	59.4	59.3	151.3	270.0
1998	50.5	51.5	95.3	197.3	50.5	51.5	155.3	257.3	62.4	63.4	174.0	299.8
1999	52.0	54.1	104.8	210.9	52.0	54.1	178.6	284.7	65.5	67.9	200.1	333.5
2000	53.6	56.8	115.3	225.7	53.6	56.8	205.4	315.8	68.8	72.6	230.1	371.5

Source: Mission estimates.

RWANDA - ENERGY AND CAPACITY BALANCES

Consumption Projection of Scenario B

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1. Demand (GWh)											
a. Projected consumption a/	105.2	111.4	117.8	125.6	136.1	147.9	161.2	176.1	192.8	211.8	233.2
b. Losses b/	22.0	24.5	22.4	23.9	22.2	24.1	26.2	28.7	31.4	34.5	38.0
c. Required generation	127.2	135.9	140.2	149.5	158.3	172.0	187.4	204.8	224.2	246.3	271.2
2. Supply (GWh)											
a. Domestic plants c/	108.4	82.4	82.4	82.4	82.4	82.4	82.4	82.4	82.4	82.4	82.4
b. Ruzizi I d/	18.8	50.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
c. Ruzizi II e/	-	-	46.7	46.7	46.7	46.7	46.7	46.7	66.7	66.7	66.7
3. Energy Balances (GWh) f/											
a. Without purchases from Ruzizi I	(18.8)	(53.5)	(11.1)	(20.4)	(29.2)	(42.9)	(58.3)	(75.7)	(75.1)	(97.2)	(122.1)
b. With imports of Ruzizi I as indicated in 2.b	0	(3.5)	18.9	9.6	0.8	(12.9)	(28.8)	(45.7)	(45.1)	(67.2)	(92.1)
4. Capacity Balances (MW)											
a. Peak demand g/	24.9	26.6	27.5	29.3	31.0	33.7	36.7	40.2	44.0	48.3	53.2
b. Installed capacity											
(i) domestic plants	26.6	26.6	26.6	26.6	26.6	26.6	26.6	26.6	26.6	26.6	26.6
(ii) Ruzizi I h/	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
(iii) Ruzizi II e/	-	-	8.9	8.9	8.9	8.9	8.9	8.9	13.3	13.3	13.3
c. Capacity surplus											
(i) without Ruzizi I i/	1.7	0	8.0	6.2	4.5	1.8	(1.2)	(4.7)	(4.1)	(8.6)	(13.3)
(ii) with Ruzizi I as indicated in 4.b(ii)	5.2	3.5	11.5	9.7	8.0	5.3	2.3	(1.2)	(0.6)	(4.9)	(9.8)

a/ Corresponds to Scenario B of Annex 5.1.
b/ Estimated at 18% in 1988, 16% in 1989 and 1990, and 14% in the period 1991-2000.
c/ The guaranteed energy of Ntaruka is estimated to be 22.0 GWh, of Mukungwa I, 45.0 GWh, of Gisenyi, 5.4 GWh, and Gihira, 10.0 GWh, which gives a total of 82.4 GWh. These figures may be conservative since in 1987 Ntaruka produced 28.1 GWh, Mukungwa, 60.5 GWh, Gisenyi, 8.2 GWh, and Gihira 11.5 GWh, for a total of 108.3 GWh. We assume that no new plants are built by Rwanda during the period.
d/ Contractual arrangements for the purchase of power from Ruzizi I specify no minimum energy supply, thus allowing great flexibility for Rwanda. The 1988 level of energy supplied by Ruzizi I was determined by the shortfall of domestic plants; for 1989 and thereafter the 30 GWh represents a reference level which would, in practice, be adjusted in function of supply from Ruzizi II to achieve an energy balance of 0.
e/ Corresponds to 1/3 of the energy produced or installed capacity of Ruzizi II. The third unit is assumed to be operational at the beginning of 1995.
f/ A figure in parenthesis indicates a negative amount.
g/ Calculated from the required generation using 5,100 hours of utilization.
h/ Corresponds to the subscribed power. The installed capacity of Ruzizi I of 28.2 MW and peak demand in Zaire was 16.3 MW in 1987.
i/ Does not take into account the reserve requirements. The existing contract to purchase power from Ruzizi I allows ELECTROGAZ to increase the subscribed power when required.

Source: Mission estimates.

DEMAND AND SUPPLY IN THE INTERCONNECTED SYSTEM OF BURUNDI, RWANDA, AND ZAIRE-KIVU
(GWh)

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1. Demand a/											
a. Burundi	99.7	101.6	126.0	155.5	163.4	167.6	171.0	174.1	176.9	179.7	182.4
b. Zaire	70.1	69.3	73.2	75.4	77.5	115.9	121.0	127.1	142.3	147.1	151.9
2. Supply											
a. Burundi b/	99.7	114.0	160.7	171.4	171.4	171.4	171.4	171.4	191.4	191.4	191.4
b. Zaire c/	70.1	160.0	206.7	206.7	206.7	206.7	206.7	206.7	226.7	226.7	226.7
3. Available Exports to Rwanda	-	103.1	168.2	147.2	137.2	94.8	86.1	76.9	98.9	91.3	83.8
4. Import Requirements of Rwanda	18.8	53.5	11.1	20.4	29.2	42.9	58.3	75.7	75.1	97.2	122.1
5. Surplus in the EGL region	-	49.6	157.1	126.8	108.0	51.7	27.8	1.2	23.8	(5.9)	(38.3)

a/ Estimates used in the "Etude de Tarification de l'Electricité de laCentrale Ruzizi II", BCEOM, June 1988. Corresponds to scenario B1 which assumes a medium rate of economic growth and investments in transmission and distribution executed in accordance with the expansion plans.

b/ Includes 80.0 GWh from Rwegura, 34.0 GWh from Mugera, 7.0 GWh from Ruryironza (interconnected in 1990), 3.7 GWh from Gikonge (interconnected in 1990), and 46.7 GWh from Ruzizi II (66.7 GWh in 1996 and after).

c/ Includes 160 GWh from Ruzizi I and 46.7 GWh from Ruzizi II (66.7 GWh in 1995 and after).

d/ A figure in parenthesis indicates a negative amount.

Source: Mission estimates.

ELECTROGAZ

Generating Facilities

	Unit Number	Capacity (MW)	Year Installed	Latest Rehabilitation
HYDRO				
Gisenyi	1	0.5	1958	1987
	2	0.5	1958	1987
Ntaruka	1	3.75	1958	1988
	2	3.75	1958	1986
	3	3.75	1976	1987
Mukungwa	1	6.23	1981	-
	2	6.23	1981	-
Gihira	1	0.9	1985	-
	2	0.9	1985	-
DIESEL				
Kibuye	1	0.5kVA	1978	-
Kibongo	1	0.75	1974	-
Gatsata	1	0.7	1978	-
	2	0.7	1978	-
	3	0.7	1978	-
Gisenyi	1	0.2	1979	-
	2	0.1	1979	-

Source: ELECTROGAZ.

ELECTROGAZ

Electricity Supply 1983-87

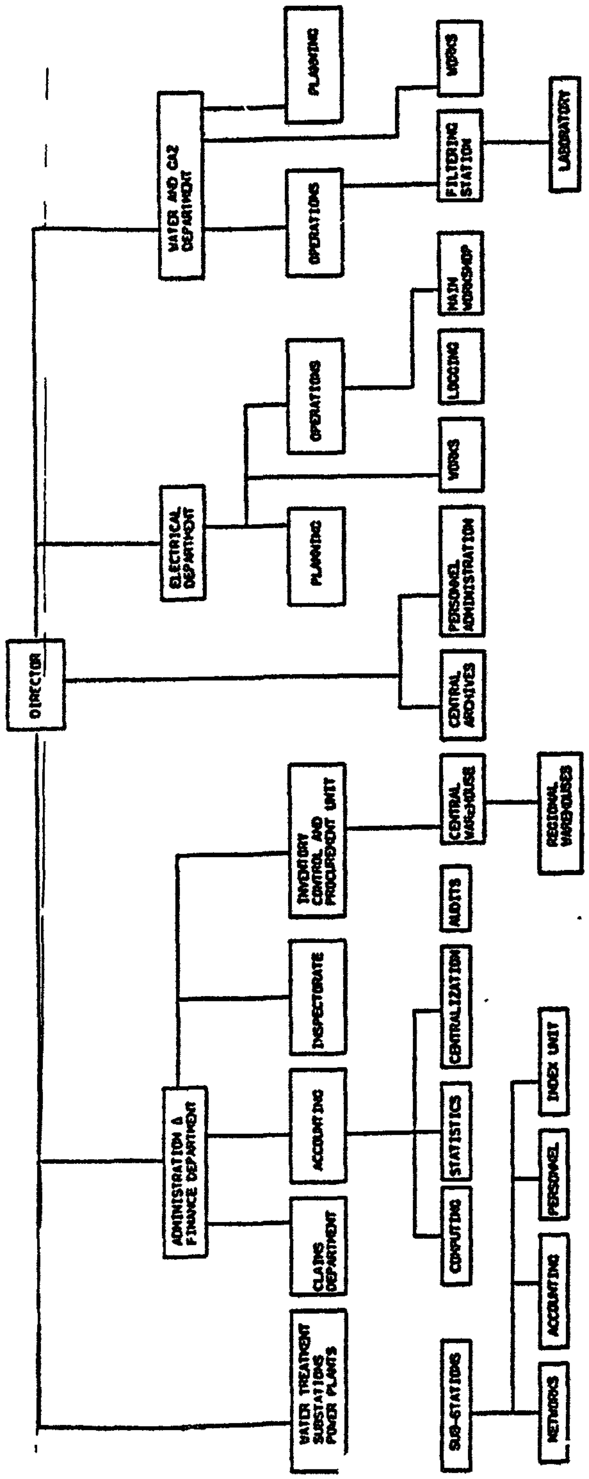
(GWh)

Power Plants	1983	1984	1985	1986	1987
Hydroelectric					
Mukungwa	53.60	58.33	55.23	55.85	60.54
Ntaruka	25.83	29.15	27.27	23.96	28.06
Gisenyi	5.98	6.42	5.66	6.03	8.22
Gihira	-	-	1.83	8.80	11.52
Diesel					
Gatsata	0.18	0.08	-	0.31	0.12
Imports					
Ruzizi I	12.45	10.87	20.67	21.85	18.79
Total Supply	98.04	104.85	110.66	116.80	127.25
of which imports	12.7%	10.4%	18.7%	18.7%	14.8%

Source: ELECTROGAZ.

ELECTROGAZ

Organizational Listing



RWANDA: POWER SECTOR INVESTMENT PLAN
(Millions of 1987 US$)

PROJECT TITLE	Total Project Cost			1988	1989	1990	1991	1992	1993	After 1993
	Foreign	Local	Total							
GENERATION										
Mukungwa II (3.6 MW)	11.27	5.55	16.82	0.00	0.00	5.05	8.41	3.36	0.00	0.00
Rukarara (9.4 MW)	21.50	10.59	32.09	0.00	0.00	7.22	12.03	10.43	2.41	0.00
Rusomo-Rugezi (3 MW)	9.29	3.98	13.27	0.00	0.00	0.00	2.65	6.66	3.98	0.00
Keya (1.8 MW)	3.10	1.33	4.43	0.00	0.00	2.22	2.21	0.00	0.00	0.00
10 Microcentrales	4.00	2.27	6.27	0.00	1.25	1.25	1.25	1.25	1.25	0.00
Nyabarongo (9-14 MW)	28.28	12.12	40.40	0.00	0.00	0.00	1.99	16.16	14.14	8.11
Akanyaru (2-2.5 MW)	7.95	3.41	11.36	0.00	0.00	0.00	2.27	5.68	3.41	0.00
Ruzizi II 3ème groupe	2.54	0.28	2.82 a/	0.00	1.13	1.69	0.00	0.00	0.00	0.00
Rusomo Falls	38.00	12.60	50.60	0.00	0.00	0.00	0.00	12.04	12.04	26.51
TOTAL GENERATION	125.93	52.13	178.06	0.00	2.38	17.43	30.82	55.57	37.23	34.62
TRANSMISSION										
Gifurwe-Kirambo	0.50	0.34	0.84	0.28	0.56	0.00	0.00	0.00	0.00	0.00
Rehab/Ext 6 Urban Centers (Byumba, Gitarama, Cyangugu, Bugarama, Gikongoro, Rwamagana)	7.54	1.60	9.15	0.27	2.38	4.21	2.29	0.00	0.00	0.00
Alimentation en élec. des chefs-lieux des sous-préfectures - Rehab. Jabana-Rutongo/Ext. Murambi - Gasiza-Giciye-Kabaya-Rubaya - Nyamirambo-Butamwa-Kanazi	2.41	0.43	2.84	0.85	1.42	0.57	0.00	0.00	0.00	0.00
Kilinda-Kaduha-Gikongoro	1.32	0.56	1.88	0.00	0.38	1.50	0.00	0.00	0.00	0.00
Electr. rurale; ext. des lignes électriques en milieu ruraux	14.41	6.17	20.58	0.00	0.00	2.68	8.23	7.61	2.06	0.00
TOTAL TRANSMISSION	26.18	9.10	35.29	1.41	4.73	8.95	10.52	7.61	2.06	0.00
DISTRIBUTION										
Electrification des quartiers périphériques de Kigali	3.20	1.37	4.57	1.04	1.10	1.22	1.21	0.00	0.00	0.00
Eclair. public de Kigali	3.30	1.41	4.71	1.05	1.22	1.22	1.22	0.00	0.00	0.00
Eclair. public de Butare (2ème phase)	0.36	0.16	0.52	0.52	0.00	0.00	0.00	0.00	0.00	0.00
Extension BT Cyanika, Gifurwe, Gakene	0.52	0.22	0.74	0.74	0.00	0.00	0.00	0.00	0.00	0.00
ELECTROGAZ self-financed extensions	2.20	0.94	3.14	1.08	1.08	0.98	0.00	0.00	0.00	0.00
TOTAL DISTRIBUTION	9.58	4.10	13.68	4.43	3.40	3.42	2.43	0.00	0.00	0.00
TOTAL INVESTMENTS	161.69	65.34	227.03	5.84	10.52	29.81	43.77	63.18	39.29	34.62

a/ Rwanda's 1/3 share of total cost.

Source: Ministry of Public Works and Energy; ELECTROGAZ.

COST OF PROPOSED POWER PLANTS
(In US$)

Plant	Cost in Millions of 1987 US$	Capacity in MW	Cost/kW Installed
Mukungwa II	16.82	3.6	4,700
Rukarara	32.01	9.4	3,400
Rusumo-Rugezi	13.27	3.0	4,420
Keya	4.43	2.0	2,300
Nyabarongo	40.40	9 - 14	2,900 - 4,500
Akanyaru	11.36	2 - 2.5	4,500 - 5,700
Ruzizi II, third unit	8.46	13.3	600
Rusumo Falls	50.60	27.3	1,900

Sources:
- "Etudes de l'Aménagement hydroélectrique de Mukungwa II et Rukarara; (Motor Columbus/Oscar von Miller; janvier 1988)".
- "Expertise sur la Stratégie de Développement de Nouvelles Centrales hydroélectriques au Rwanda; (DECON; mai 1988)".
- "Aménagement hydroélectrique des Rusumo Falls; (by the Belgian engineering firm TRACTOBEL, mars 1988)".
- Mission estimates.

RURAL ELECTRIFICATION

Criteria for Project Acceptability

Introduction

1. Developing countries and donors are putting increased amounts of resources into rural electrification but, in may cases, projects are not subject to the same rigorous cost/benefit analysis that is recommended for other investment projects. Sometimes it is confusingly argued that rural electrification is justified on the basis of some non-quantifiable social benefits. In other cases, inflated and unrealistic tariff revenues are considered as the only benefits. The consequence of the erroneous analysis is that scarce resources are wasted in investments that are neither socially nor economically desirable and that the allocation of the limited funds available to the country is not done correctly.

2. This note explains how the social and economic justification of rural electrification projects should be done following the traditional methodology of cost/benefit analysis. Households, farms, agro-industries, and commerce derive benefits from the use of electricity and these benefits can be measured, as is customary practice in the appraisal of development projects, by the amount of income that these families and businesses are prepared to spend on electricity. The correctly measured benefits should be compared with the costs of the project, calculating the net present value and the internal economic rate of return, to determine if the project is desirable. Rural electrification projects with negative net present value or internal economic rates of return below the opportunity cost of capital should not be undertaken.

Forecasting Demand

3. The first task in the definition of a rural electrification project is to forecast demand for electricity over a reasonable period of time. The basis for this forecast is an exhaustive survey of the population and economic activities in the region of the project. The survey should be tailored to the area under investigation, but it should at least identify: (i) type and number of potential consumers; (ii) socio-economic characteristics of consumers; (iii) physical characteristics of houses; (iv) principal economic activities; and (v) existing and potential uses of energy.

4. While surveys are normally undertaken in all rural electrification projects, demand forecasts based on them are generally too optimistic. The first point to consider is that existing consumers will not connect immediately to the electric grid. Sometimes this is due to

the connection charges and tariff rates established by the electrical companies, but there is also quite a lot of social inertia in rural areas which results in low adaptation to changes. Evidence from the rate of connections in already executed similar projects should be used to make an adequate estimate of what would happen in the new project. Another point to consider is that electrification per se will not automatically produce growth. For this to occur other investments in the region will have to be made. Regional development plans and budgets should be examined to forecast the growth in the number of each type of consumers, including population and businesses, and the experience of other areas should be used to forecast the level and growth of consumption per consumer. Street lighting and consumption of schools, health center, and other administrative offices can be estimated directly from available technical coefficients.

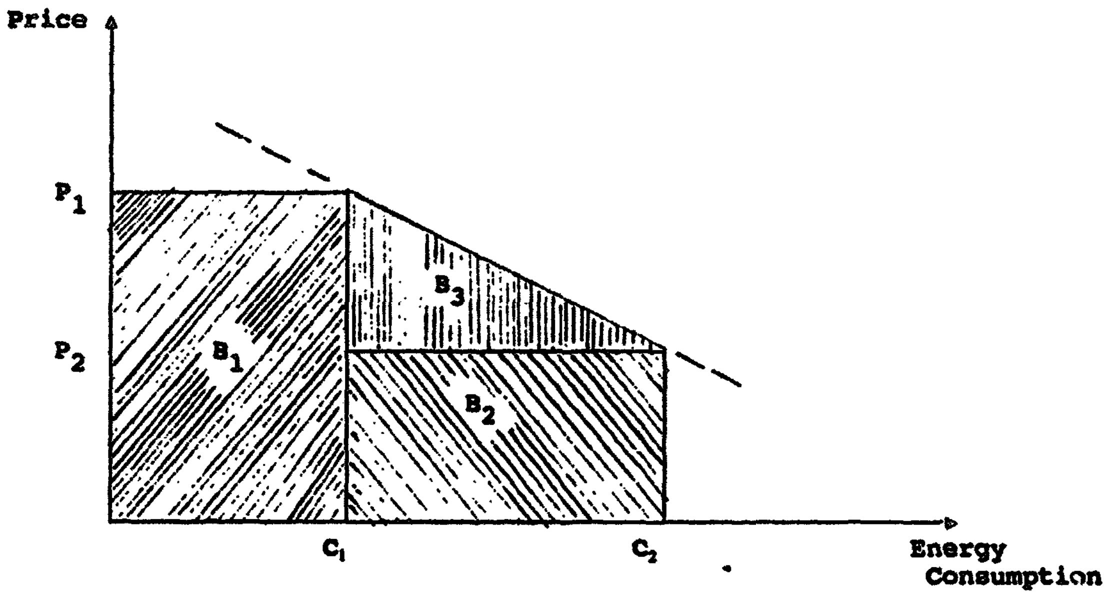
Analysis of Alternatives

5. Rural electrification is generally considered to be the extension of the national electric grid into a new area. But areas can also get electricity developing local sources, such as diesel-powered generators or local minihydro sites. For small consumption and/or for remote areas it is often cheaper to meet the electricity needs through local supply. In those circumstances, the capital costs of diesel generators are normally lower than the extension of the electric grid and compensate for the higher fuel and operating costs. This is the reason why, in the initial phases of electrification in isolated areas, private businesses may install their own generators and sometimes even partially supply a neighboring town.

6. In all rural electrification projects a comparison should be made between the development of local supply and the extension of the national electric grid. In a new locality it may be advantageous to install first diesel generators and then create a market for electricity. The interconnection to the electric grid will then be done only when consumption surpasses a certain minimum level. Governmental decision-makers and donors should insist that an analysis of alternative sources of electricity supply be done before embarking on the extension of transmission lines.

Calculation of Benefits

7. Demand curves should be constructed for the principal types of consumers in each project area. These curves are based on the surveys undertaken to forecast demand and should distinguish between: (i) the cost and kWh equivalency of current consumption of alternative forms of energy being used in the area (lighting, autogeneration, diesel engines, and other equipment to be substituted); and (ii) projected future consumption of electricity at the prevailing tariff rates. A typicical yearly demand curve is depicted below.



In the above diagram, "C_1" indicates the current level of consumption (in kWh equivalent) of alternative forms of energy. "P_1" indicates the implied price per kWh equivalent of that energy. "C_2" indicates the projeted level of consumption of electricity after the project. "P_2" indicates the prevailing tariff level charged by the company for that consumption. The area covered by rectangle "B_1" represents consumers' annual expenditures on (relatively expensive) alternative forms of energy in the "without project" situation. Rectangle "B_2" represents the additional amount of energy the consumer is expected to use as a result of the project (because of the fall in price) times the average electricity tariff rate. And triangle "B_3 represents the "consumer surplus", which is the difference between what consumers would be willing to pay for each additional unit of energy consumed and what they are actually charged by the electric company. The total benefit of the project is equal to the sum of areas "$B_1 + B_2 = B_3$", or

$$P_1 \times C_1 + P_2 (C_2 - C_1) + 1/2 (P_1 - P_2) (C_2 - C_1)$$

8. In order to calulate "B_1", expenditures on alternative forms of energy need to be estimated for each consumer group. In the case of households, commercial establishments, schools, and other administrative offices, electricity will principally be used as a substitute for fuels and candles currently used for illumination. In order to calculate the quantities involved, the numer of residential and other users in each project area must be multiplied by an estimate of the average level of fuel and candle consumption in non-electrified households. An allowance must also be made for the substitution of electricity in other uses (e.g., cooking, refrigeration). In the case of agricultural producers and agro-business, an inventory should be made of currently employed diesel powered machinery (by type and capacity). Using technical coefficients and assumed utilization factors, the total substitutable consumption of diesel oil can be calculated.

9. The quantities of fuel determined following the procedure of the above paragraph must be multiplied by their estimated CIF cost. This will give the total expected economic value of savings in alternative forms of energy (the area "B_1") in each project area. A caveat for the economic analysis is that in calculating the area "B_1", price "P_1" should be expressed in terms of economic prices (i.e., net of taxes and subsidies), whilst calculating the area of "B_3", price "P_1" should reflect actual market costs (including taxes and subsidies) because it defines the slope of the demand curve (and hence the area "B_3").

10. The area "B_2" is determined by the average price of electricity to rural consumers (price "P_2" in the diagram) and the increase in consumption of energy ("C_2" - "C_1") due to the fall in price (from ("P_1" to "P_2"). The level of "P_2" is generally a known data and the calculation of energy consumption in the "without project" ("C_1") has been described in para. 8 above. Energy consumption "with the project" ("C_2") can be estimated from data on average level of electricity consumption by type of consumers in recently electrified areas. In the case of residential consumers, average consumption should be broken down by size and type of dwellings. It must be noted that in the first years of electrification only a fraction of the potential consumers connect to the electric system. Also, energy consumption per household increases rapidly in the first year after connection as electric lights and priority appliances are purchased, and then declines reaching close to saturation levels near the fourth year. These facts should be considered in the estimation of electric consumption with the project.

11. The area "B_3", representing the value of the "consumer surplus", is calculated by multiplying the increase in energy consumption due to the project ("C_2" - "C_1") by the fall in the price of energy ("P_1" - "P_2"), times one-half. In this case, however, subsidies and taxes have been included in the cost of alternative forms of energy, since they represent part of the consumer's perceived cost in the "without project" situation. "P_1" was thus obtained by dividing the total consumer expenditure on alternative forms of energy before the prcject by the assumed initial energy consumption level "C_1".

12. Practical experience indicated that benefits of energy substitution (area "B_1") and of consumer surplus (area "B_3") are generally more than 60% of the total benefits of a rural electrification project. When these benefits are not measured there is a huge under-estimation of benefits. Decisions based exclusively on tariff revenues will not justify most rural electrification projects and therefore consultants over-estimate demand to approach some acceptable internal economic rate of return.

Project Acceptability

13. Once demand and benefits have been estimated, it is necesssary to compare the time-stream of costs and benefits over the useful life of the project on a present worth basis. The calculation of net present values and internal economic rates of return follow customary practices of cost/benefit analysis. Shadow-price adjustments for foreign exchange and unskilled labor should be made on the basis of the country's macro-economic situation.

14. A rural electrification project should be executed only if the internal economic rate of return is greater than the opportunity cost of capital. When this is not the case, the contribution of electricity to raise income is limited and does not compensate for the resources used. Sometimes this may be due to the high cost of the project. In those cases, network layout and equipment capacity should be re-examined to find out if savings in investment costs are possible. But the low economic returns may also indicate that local economic activity is very small and that other investments are needed to develop the area. If this is the case, rural electrification should be postponed until the additional infrastructure is in place. The economic rate of return calculated according to sound cost/benefit analysis provides a clear signal of the adequacy of the proposed investment.

MARGINAL COST OF ELECTRICITY

1. The LRMC of electricity in the interconnected network of Rwanda has not been estimated in a comprehensive manner based on a long-term investment plan. The Power Master Plan study now in progress includes a tariff study based on the LRMC of future least-cost development of the Rwandan network. In the interim, the calculation below, based on the best available information and the mission's assumptions, gives an approximate value that can be useful in evaluating present rate levels and energy substitution possibilities.

Generation Cost

2. In the absence of reliable cost estimates for future power plants in Rwanda, Ruzizi II is treated as the marginal plant. It should be noted, however, that preliminary costs for power plants in Rwanda show them to be more costly than Ruzizi II, so that the real generation cost of the system may be underestimated by using Ruzizi II.

3. The calculations below are based on 1988 prices. Life of the installation is as follows: (i) 50 years for the civil works, and (ii) 35 years for electro-mechanical equipment. A third 13.3 MW unit enters into operation in 1994. The only major renewal is the turbines after 35 years of operation (2023-24). At the end of the 50-year period of the calculation, the turbines, renewed 13 years earlier, would have a residual value of 60% of their renewal cost while civil works retain their full original value.

(All Costs in SDR '000s)

Year	Construction Cost	Operating Cost	Total Cost	Production (GWh)
1978	300	0	300	0
1979	300	0	300	0
1980	300	0	300	0
1981	250	0	250	0
1982	50	0	50	0
1983	50	0	50	0
1984	6,593	0	6,593	0
1985	9,704	0	9,704	0
1986	15,633	0	15,633	0
1987	20,870	0	20,870	0
1988	22,055	0	22,055	0
1989	2,000	750	2,750	90
1990-93	0	750	750	140
1994	7,600	750	8,350	140
1995-2022	0	750	750	200
2023	11,010	750	11,760	200
2024	11,010	750	11,760	200
2025-36	0	750	750	200
2037	-42,228	750	-41,478	200

Source: SINELAC and mission estimates.

4. The construction costs between 1978 and 1988 were converted to 1988 values using unit values of exports of manufactured goods from developed countries. The present value at year 1988 of all investment and operating costs with a discount rate of 10% is SDR 118,568 thousand and the present value of production is 1,674.5 GWh. The estimated marginal generation cost is therefore SDR 0.07/kWh. At an exchange rate of US$1.30 = SDR 1.00 this corresponds to US$0.091/kWh (approximately RF 6.83).

Energy Cost of Transmission

5. With generation losses equal to 2%, the cost of energy sent to the system would be US$0.093/kWh (0.091 x 1.02). The Ruzizi II hydroelectric plant is linked to the Mururu substation by a 15 km transmission line for which total investment costs are equal to US$961,000; useful life of the station is estimated to be 30 years. The line will conduct 46.7 GWh between 1989 and 1994, and 66.7 GWh after 1995. Assuming that annual operating costs are 3% of investment costs and that transmission losses are 2%, we obtain a value for total transmission costs equal to US$0.004/kWh, which is understandably low given the limited investment required. The resulting marginal cost of energy transferred from the transmission to the distribution level would therefore be US$0.097.

Energy Costs at the Medium Voltage Distribution Level

6. There are no reliable estimates of development costs at the distribution level. SAUR-Afrique and EDF in the 1987 Tariff Study give values for the MV and high voltage (HV) network between US$156 and US$352 per kW, including operating costs. These values were obtained from four different consultants who established them through experience with project execution or in feasibility studies for proposed projects (LAVALIN, BETELEC, ENERGIEPLAN-GMBH, and OSCAR VON MILLER). Since the average number of hours of utilization for high and MV consumers is 3,600 the energy cost of distribution would vary between US$0.043 and US$0.098 per kWh.

7. Based on the estimations of the previous paragraphs and with losses of 4%, the costs of the energy sold directly from the MV network is between US$0.14 and US$0.19/kWh, averaging US$0.17/kWh. This value should be compared with the present average tariff of US$0.13/kWh applied for capacities below 100 kW and US$0.10/kWh for capacities above 100 kWh.

Energy Cost at the Low Voltage Distribution Level

8. The above mentioned tariff study by SAUR/EDF estimates the additional costs of the low voltage (LV) distribution network at between US$128 and US$277/kW, including investments and operating costs. All the high voltage (HV) network and a substantial part of the MV network are also used to feed LV users. Since there is no way to distribute these costs without detailed studies of the whole power system, we will assume that three-fourths of the estimated high and MV costs should be imputed to LV distribution. Total development costs of transmission and distribution will therefore be

between US$245 and US$451/kW or between US$0.061 and US$0.135/kWh, with an average utilization of 4,000 hours.

9. With 8% losses between transmission and distribution, the cost of the energy sold a LV levels is between US$0.16 and US$0.24/kWh, or an average of US$0.20. This value should be compared with the present average LV rate of US$0.11/kWh.

LAKE KIVU - METHANE GAS RESOURCE BASE

Origin

1. The origin of the methane in the Lake is not fully known. It could come from geological, biological or a combination of sources. In contrast, the way gas is dissolved in deep waters and gas-rich water layers are kept at great depth is well understood. Due to volcanic characater of the Region, the temperature of Lake Kivu increases with depth. The deep warm water is more soluble to minerals than the cool water above it and the weight of the minerals dissolved makes the water at the bottom denser than that at the top (in spite of its high temperature). Convection, the normal movement of warm fluids up and cool fluids down, is thus prevented and stability is obtained. Below a depth of about 270 meters, temperatures and pressures (about 30 atmospheres) are such that the water can absorb substantial quantities of methane and other gases.

Nature and Composition

2. About 1.4 Nm^3 of gas is dissolved in each cubic meter of water in the lower strata. Most of the gas is carbon dioxide (about 74%) and only a fraction is methane (about 25%).Yet, no practical process has been identified whereby gas would be extracted in situ. To extract the gas deep water has to be raised to the surface where lower pressure makes gas come out of solution. Such handling of massive volumes of water is a major constraint. It governs the whole concept and design, and thus the costs and economics of gas production plants. Furthermore, due to its low methane content, crude gas extracted at the surface is not flammable. To be used as a burner fuel, and for its supply by long-distance pipeline to be economic, its methane content has to be increased by getting rid of the carbon dioxide; the more so if compression or liquefaction of gas is considered for the transport to markets as CNG or LNG. This is another constraint which adds to gas production costs. Finally, dissolved gas contains hydrogen sulfide. This causes equipment to rust and exposes it to wear (unless corrosion-proof materials are used, which add to costs), but only in traces of up to 0.05% which makes its extraction for use such as in the manufacture of matches uneconomic by industry standards.

Behaviour and Risks in Production

3. The gas production process used in the Cap Rubona pilot plant is straightforward. Water from the bottom is brought to the surface thru a pipeline. As water rises it reaches zones where the water column pressure is progessively lower so that the gas comes out of the solution. Rising gas bubbles then exert enough upward force on the water to avoid the need for pumps once the process is started. Gas is collected at the surface in a capping bell from which it is circulated to washing columns where its methane content is raised through redissolving carbon dioxide in a flow of surface water. Degassed deep water and carbon dioxide-rich water are disposed of at the surface of the Lake.

4. On a larger scale over the years, continued extraction at one point and disposal of water at the lake's surface would entail considerable risks:

(a) because deep-water is collected continuously from the same bottom point, the resource may come locally to exhaustion; and

(b) because used deep-water is not returned to the intermediate depth corresponding to its density, a pattern of vertical circulation may be set in motion that would mix the various layers of the Lake. As a result, lower strata would cool, gas would come out of the solution, and bubbles would stir deep-water up nearer the surface where the pressure is lower with the same result. Should the destabilisation of the Lake spread on a large scale not only would the entire gas resource be wasted but a disastrous conflagration could be fueled, if the escaping gas were ignited.

5. Comprehensive studies on the behaviour of the Lake under continuing, large-scale extraction 1/ have identified these risks and defined the rules that would have to be observed to ensure safety both during actual gas production operations and in plans for overall development of the Lake over time.

(a) Degassed deep-water would be returned to a depth corresponding to its density so that it stays at the depth at which it is disposed of. This requires the provision for water-returning pipe(s) of significant length which increases costs of production plants. Prior mixing of degassed deep-water with surface water in appropriate proportion may be a way to mitigate the problem: lower density of returned water requires a lesser depth for its disposal, thus a shorter returning pipe, but greater volumes of returned water require a pipe of larger diameter.

(b) Continuous extraction of deep gas-rich water tends to lower its top level. Although horizontal circulation inside layers compensates for the phenomenon this sets a strict limit to the rate of water extraction from a given fixed bottom point, as is the case in gas production plants located onshore.

6. Despite these considerations, safe limits in the rate of water extraction are not likely to constitute an obstacle to gas production even at the large industrial scale projected for the "Grands Projets". Even disregarding the natural renewal of the gas resource over time which is estimated at 250 million Nm^3 per year, annual production of 50 million Nm^3 of gas (equal to two simultaneous "Grands Projets" or the energy equivalent of one-half of the total 1987 petroleum consumption in Rwanda) will lower the present top-level of gas-rich deep-water by a maximum of two meters after ten years of sustained extraction.

1/ *The most exhaustive and documented study is that of SOGREAH, whose services were subcontracted by TECHNIP for its 1986 feasibility study of the "Grands Projets". Risks reviewed also pertain to in-depth currents, seismic and volcanic hazards.*

LAKE KIVU - METHANE GAS TECHNOLOGIES

Technologies in Use at Cap Rubona

1. TRACTEBEL, which has a close involvement with the Cap Rubona plant, regards the technology used there as applicable to a net production capacity four times larger than the present and considers gas pipelined to the brewery to be cost-competitive with fuel oil by a significant margin despite current low oil prices. The "Grands Projets" studied by TECHNIP ENGINEERING make use, with some improvements, of the same technologies. But none of the "Grands Projets" envisaged would be economically viable.

2. This apparent contradiction can be explained. The technologies used to date, although suboptimal in various respects, are economic on the Cap Rubona site because two favorable conditions, not found anywhere else around the Lake, exist locally:

(a) a very steep slope that extends from the shoreline to the minus 300 meter isobath: consequently pipes for both extraction and disposal of deep-water have a limited length and thus an acceptable cost; and

(b) the immediate proximity of a major fuel consumer for the bulk of the gas produced: consequently pipeline length is minimal and gas supply cost is negligible.

3. In contrast to the Cap Rubona case, the onshore locations proposed for the gas production plants of the "Grands Projets" merely are "least bad" sites in various respects. (The length to depth ratio of the water extracting pipe(s) increases from 2.7 at Cap Rubona to 4 and even more at the best alternative sites). The advantage, from an efficiency and economic point of view if not from necessity, of locating gas production plants offshore (where the above ratio is 1.0 by definition) was not clearly recognized and one of the basic principles of the whole study was therefore not well founded. Furthermore, the primary fuel users envisaged for the "Grands Projets" would be located at a much greater distance from the Lake than the brewery (in most cases by an order of magnitude of 100 to 1). This increases pipeline costs from a negligible to a significant component of the total gas development cost.

4. The low degree of relevance for Lake Kivo of the envisaged technologies and solutions, which are applicable to the most common type of gas development: production onshore, gas transport by pipeline, massive end uses, is increasingly being recognized. Once the need to reduce costs of gas production and transport was acknowledged in order to make the apparently only feasible bulk end-user (i.e., the cement plant) more economic, attention was redirected to a more efficient production process (gas bubbling at higher than atmospheric pressure) and to a more appropriate transport mode (CNG instead of pipeline).

5. This is a significant step in the right direction, but it still falls short of recognizing the merits of (i) going deliberately offshore for production, (ii) converting the gas to CNG or LNG for transport as an alternative to, or in combination with pipeline transport, and (iii) focussing on dispersed medium and even small consumers, for whom the relevant means of gas distribution is in the form of CNG or LNG (in addition to supplying the Mashyusa cement plant).

Improved Offshore Appropriate Technologies

6. For gas production, the ultimate technology would be to extract gas in situ, thereby eliminating the cumbersome and costly need to bring massive volumes of deep water up to the surface and back again to a certain depth. Investigations need to be made to establish the feasibility of existing technologies in this respect. There are two intermediate improvements within reach: first, gas can be made to escape from the solution at more than atmospheric pressure. As dictated by physical laws, less total gas is then released from water, but its methane content is higher. Second, mixing deep water with intermediate depth water, on its way to the surface inside the pipe, would further help to increase the methane content of the gas by keeping carbon dioxide dissolved in unsaturated water. What is sought in both instances is to reduce the need for subsequent elimination of carbon dioxide from crude gas, thereby cutting costs of related equipment and minimizing energy (or gas) consumed in the methane enrichment process at the surface. One can even imagine a crude gas that, without further processing, would be flammable and as such directly usable as a burner fuel.

7. Following conclusive laboratory experiments, field tests of gas extraction at higher than atmospheric pressure were completed at the Cap Rubona pilot plant, but unfortunately without the element of mixing waters. Still, the results were very encouraging. They will make possible the design of gas production modular units which appear very appropriate to locations offshore, with improved performance and lower capital cost.

8. For gas supply to markets, the alternative to transporting by pipeline is on-site gas compression into CNG or liquefaction into LNG for shipment by barge and from the landing point transport by truck or trailer, or by pipeline, depending on the consumers' location and the quantity of gas demanded. On the one hand on-site conversion into CNG or LNG is a necessity for gas production plants located offshore, for it would be difficult to use pipelines linking floating platforms to the shore. On the other hand CNG/LNG distribution is particularly well adapted to supplying gas to small and medium-sized dispersed energy markets, which is likely the common case in Rwanda. Overall, therefore, the CNG/LNG option appears to be the appropriate solution for a phased development of Lake Kivu gas, that would be based on offshore CNG/LNG production and on transport modes that reflect the gas demand of fuel substitution markets in the vicinity of the Lake.

Table 1: RWANDA: SOLAR LIGHTING SYSTEMS

System:	GITARAMA						BUFMAR						ELECTROGAZ					
Specifications	#	W	V	Hr/d	kWh/y	Cost/RF	#	W	V	Hr/d	kWh/y	Cost/RF	#	W	V	Hr/d	kWh/y	Cost/RF
Solar panels	1	19	12			25,000	3	38	24			75,690	2	80	24			141,892
Lights	4	8	12	1	17	15,000	4	8	24	2	23	14,964	3	20	24	3	66	36,486
							4	13	24	2	38	17,052	4	13	24	3	57	33,405
							3	20	24	2	44	15,660	12	8	24	3	105	87,568
Total (Lights)	4	8	12	1	17	15,000	11	41	24	6	105	47,676	19	41	24	9	228	157,459
Battery	1		12			4,000	2	24				11,339	12		2			42,032
Regulator & fuses						6,000						7,830						28,459
Installation (materials)						8,000	Cables					10,000						0
Other						0	Mounting equipment					10,000	Kit eclairage					152,027
FOB cost						58,000						162,535						521,870
Transport & Insurance						1,740						24,380						78,281
CIF costs						59,740						186,915						600,151
Duties, etc.						2,987						18,691						60,015
Installation (labor)						3,200						19,200						32,000
System cost						65,927						224,806						692,166
Cost per kWh					US$	RF					US$	RF					US$	RF
13.7% p.a.	(1)				6.94	521					3.92	294					5.57	418
15.1% p.a.	(2)				7.65	574					4.32	324					6.14	460
18.3% p.a.	(3)				9.23	692					5.21	391					7.40	555

Notes:

- GITARAMA: System produced locally by Diocese of Gitarama. Components imported.
- BUFMAR: Installs systems in health centers. 80% of cost subsidized by the Federal Republic of Germany as development assistance.
- ELECTROGAZ: Belgian assistance to equip health centers in Kigali and Butare prefectures with solar lighting. Calculations here based on Nyagasambu configuration. Furthermore, system costs for refrigeration and sterilization have been left out for the sake of comparability. See also notes at bottom Table 2.

Table 2: RWANDA: SOLAR LIGHTING SYSTEMS

System:	GITARAMA						BUFNAR						ELECTROGAZ					
Specifications	#	W	V	Hr/d	kWh/y	Cost/RF	#	W	V	Hr/d	kWh/y	Cost/RF	#	W	V	Hr/d	kWh/y	Cost/RF
Solar panels	1	48	12			36,274	1	40	12			30,223	1	38	12			
Lights	4	8	12	2	23	20,013	4	8	12	1	15	20,480	1	13	12	4	19	
	1	13	12	4	19	5,003	2	6	12	1	2	10,490	3	8	12	2	18	
							1	13	12	4	19	5,245						
Total (Lights)	5	8	12	6	42	25,016	7	8	12	6	36	36,214	4	13	12	6	37	
Battery	1		12			9,381	1		12			8,060	1		12			
Regulator & fuses						7,330						7,052						
Installation (materials)						5,000						5,000						
Other						0	Tools testers, etc.					6,000						
FOB cost						83,001						92,548	Complete system					60,000
Transport & Insurance						12,450						13,882						9,000
CIF costs						95,451						106,431						69,000
Duties, etc.						9,545						10,643						6,900
Installation (labor)						6,400						6,400						6,400
System cost						111,396						123,474						82,300

Cost per kWh:		GITARAMA US$	GITARAMA RF	BUFNAR US$	BUFNAR RF	ELECTROGAZ US$	ELECTROGAZ RF
13.7% p.a.	(1)	4.82	362	6.33	474	4.13	310
15.1% p.a.	(2)	5.31	399	6.97	523	4.55	342
18.3% p.a.	(3)	6.41	481	8.41	631	5.49	412

Calculations based on specific recent quotations for Rwanda solar radiation regime. Battery capacities allow for 3-5 days of insufficient radiation. Transport and insurance: 15% of FOB (except GITARAMA case). Installation: based on RF 200/man-hour. Depreciation percentages refer to an annuity factor for respectively 20 years (1), 15 years (2) and 10 years (3). Interest rate 10% p.a. Maintenance costed at 2%.

Note: In an economic evaluation the duties shown would not be included. In the present context their demands do not influence the comparisons, however, and they are included for the sake of compelteness.

Source: CEAER; ELECTROGAZ; Diocese of Gitarama; various producers of equipemnt; mission estimates.

RWANDA: COST COMPARISON SOLAR AND KEROSENE REFRIGERATORS

	SOLAR		KEROSENE	
Ambient temperatures:	32 C°	43 C°	32 C°	43 C°
Vaccin Storage (liters)	14	14	32	32
Voltage	12V DC	12V DC	n.a.	n.a.
Power Consumption: kWhs/24 hr:	0.5	0.7	n.a.	n.a.
Consumption: (Kerosene) liters/24 hr.	n.a.	n.a.	n.a.	n.a.
Cost Refrigerator	US$1,263	US$1,263	US$2,117	US$2,117
Solar panels, etc.	US$2,552	US$3,296	n.a.	n.a.
Kerosene storage	n.a.	n.a.	US$400	US$400
System FOB Cost	US$3,815	US$4,559	US$2,517	US$2,517
Shipping & Insurance	US$363	US$468	US$237	US$237
System cost CIF Kigali	US$4,178	US$5,027	US$2,754	US$2,754
Total Local costs	US$774	US$859	US$375	US$375
System Installed Cost	US$4,952	US$5,886	US$3,129	US$3,129
Present value replacement at 5 years (at discounting factor of 10%):				
Refrigerator	US$1,038	US$1,038	US$1,740	US$1,740
Batteries	US$105	US$210	n.a.	n.a.
Shipping & Insurance	US$156	US$156	US$261	US$261
Fuel consumption (year)	n.a.	n.a.	US$526	US$730
Present value fuel, 10 years			US$3,230	US$4,486
Maintenance (2% & 3%)	US$609	US$723	US$577	US$577
Total (present values)	US$6,860	US$8,013	US$8,936	US$10,192
Net Cost/liter useful storage	US$490	US$572	US$279	US$319

Above based on respectively: Solar: Electrolux RCW 42 DC Electric.
Kerosene: Electrolux RCW 65.

The comparison is based on models which have been certified by the World Health Organization (WHO): relative to other kerosene refrigerators, the WHO certified refrigerator may be more expensive in terms of capital cost, but yields economies in terms of overall efficiency and dependability.)

Source: Tests conducted by WHO/UNICEF. (Expanded Programme on Immunization, The Cold Chain, Product Information Sheets, 1988/89, No. 1, pp. 52, 58).

PRESENT VALUES OF ELECTRICITY CHARGES VS. PV SYSTEMS

A. Electricity from the GRID

Case I: Connection Fee = RF 50,000; fixtures and wiring = RF 10,000 Minimum charge is for 30 kWh/month. Discount rate = 10%

Tarif/Years (RF)	10	16	20
8.5	78,802	83,941	86,052
10.5	83,226	89,574	92,181
13.5	89,863	98,023	101,376
20.5	105,347	117,739	122,830

Case II: Connection Fee = RF 10,000; fixtures and wiring = RF 10,000, Minimum charge is for 30 kWh/month. Discount rate = 10%.

Tarif/Years (RF)	10	16	20
8.5	38,802	43,941	46,052
10.5	43,226	49,574	52,181
13.5	49,863	58,023	61,376
20.5	65,347	77,739	82,830

B. PV Systems

System cost (Annex 7.1) plus 2% p.a. maintenance. Discount Rate = 10%.

System/Years	10	16	20
GITARAMA	74,028	76,243	77,152
R&S	92,413	95,178	96,313

Source: Mission.

RWANDA: ESTIMATE OF SOLAR ENERGY CONSUMPTION 1988

		Surface (m^2)	Conversion a/	Totals (kWh/yr)
I.	WATER-HEATING			
a.	BUNEP Estimates 1980:			
	4 hotels	84		
	10 Private residences	46		
	2 hospitals	30		
	village SOS	20		
		180	1506	271,013
b.	1988 Estimates (additional)			
	10 hotels b/	300		
	30 private residences	138		
	10 hospitals	150		
	20 AEBR missions	80		
	30 Missions	120		
		788	1506	1,186,433

			Number	Output (kWh/yr)	Consumption (kWh/yr)	
II.	PV ARRAYS b/					
a.	Pères Blancs		200	24	4,857	
b.	BUFMAR		130	150	19,500	
c.	ELECTROGAZ	- Coko	1	391	391	
		- Nyagasambu	1	374	374	
		- Rubona	1	377	377	
		- Kiyanza	1	376	376	
		- Gihinga	1	359	359	
		- Gakurazo	1	359	359	
		- Mareba	1	351	351	
		- Gashora	1	378	378	
		- Gikomero	1	363	363	
		- Karama	1	156	156	
		- Muhondo	1	156	156	
		- Rushashi	1	156	156	
		- Rwankuba	1	156	156	
d.	Not specified		20	24	480	28,787
III.	Radio Transmitter at Kinaniva					
		3.28 kW, 6 hrs/day =				7,183
		Grand Total:				1,493,415
		Say:				1.5 GWh/year

a/ Conversion based on 5.5 kWh/m^2, 75% availability, and 365 days.
b/ Meridien at Kigali alone has 90 m^2 of collector surface.
c/ For the PV arrays actual production is given, i.e., without allowing for losses due to battery recharging.

Source: BUNEP; ELECTROGAZ; mission estimates.

RWANDA: INVENTORY OF POTENTIAL MICRO-HYDRO SITES

Sites	Commune	Flow (l/s)	Drop (m)	Power (kW)	JC	UN	Survey	Date
Prefecture: Butare - 5 sites:								
Migina	Kigembe	500	5	17.5			Y	1981
Mirayi	Kigembe	70	30	15.0			Y	1981
Gisuma	Muguse	870	20	15.0			Y	1979
Nyiranshura	Ndora-Shyanda	0	0	5.0				
Gatobwe	Runyinya	0	0	0.0				
Identified Power				52.5				
Prefecture: Byumba - 1 site:								
Bulima	Kinyami	0	0	0.0				
Identified power				0.0				
Prefecture: Cyangugu - 6 sites:								
Karundura	Kirambo	300	65	158.0			Y	1985
Nyirakesha	Kirambo	10940	42	98.0			Y	1978
Mwanga	Gafunzo	100	10	7.0	Y	Y	Y	
Nyakabanda	Gisuma	0	0	0.0				
Kamiranzovu	Kagano	0	0	0.0				
Ntondwe	Karengera	0	0	0.0	Y	Y		
Identified Power				263.0				
Prefecture: Gikongoro - 6 sites:								
Mwogo	Mudasomwa	900	29	183.0	Y		Y	
Simbuka	Nshili	172	33	39.7	Y	Y	Y	1985
Kaviri	Kinyamara	40	20	5.0			Y	1979
Gihimbi	Rukondo	100	7	5.0			Y	1981
Mukico	Nyamagabe	17	7	0.7			Y	1977
Nshili	Mubuga	0	0	0.0				
Identified Power				233.4				
Prefecture: Gisenyi - 6 sites:								
Nkora	Kayove	500	31	150.0			Y	1981
Cyimbili	Nyamyumba	75	180	94.5	Y	Y	Y	1981
Rungu	Satinski	300	80	66.0			Y	1984
Pfunda	Nyamyumba	400	12	34.0	Y	Y	Y	1985
Gashashi	Nyamyumba	70	115	31.5			Y	1981
Buhinda	Satinski	56	15	3.7			Y	1984
Identified Power				379.7				
Prefecture: Gitarama - 3 sites:								
Kiryango	Mukingi	367	17	44.0	Y	Y	Y	1985
Mazimeru	Nyakabanda	60	80	38.5	Y	Y	Y	1986
Gasaze	Rutobwe	144	20	17.0			Y	1984
Identified Power				99.5				
Prefecture: Kibuye - 8 sites:								
Ndaba	Mabanza	100	300	240.0			Y	1981
Ndaba	Mabanza	200	70	107.0			Y	1981
Buhari	Gishyita	80	135	76.5	Y		Y	1985
Kiraro	Gishyita	405	15	42.5			Y	1985
Kagarama	Gishyita	110	44	34.0	Y	Y		
Coza	Gishyita	80	86	16.0		Y		1985
Kiruri	Mabanza	29	71	14.6			Y	1985
Gasesa	Kivumu	0	0	0.0				
Identified Power				530.6				
Prefecture: Kigali - 2 sites:								
Congoli	Musasa	70	55	27.0	Y	Y	Y	1985
Rutumba	Musasa	89	15	9.3	Y		Y	1985
Identified Power				36.3				

Prefecture: Ruhengeri - 9 sites:									
Nyamutera	Nyamutera	1200	88	850.0				Y	1981
Nyamutera	Nyamutera	1000	37	250.0				Y	1981
Nyamutera	Nyamutera	800	20	100.0				Y	1981
Mpenge	Kigombe	1350	8	75.0				Y	1981
Base	Nyamugali	180	25	30.0	Y	Y		Y	1985
Nyabeshaza	Nykinama	77	70	20.5				Y	1984
Kinoni	Nyarutovu	451	10	20.5				Y	1984
Mukinga	Cyabingo	230	26	12.0				Y	1981
Ruhurura	Nyamugali	45	30	9.5	Y		Y		
Identified Power				1372.0					
Total Power all Prefectures (kW)	2967								
Total Number of sites considered		46							
Average capacity per site (kW)			64.5						

l/s = liters/second.

Notes: Sites marked "Y" under "Survey" have been visited and surveyed. Sites marked "Y" under "JC" have been taken into consideration in the Colombani study of January 1988.

Sites marked "Y" under "UN" have subsequently been retained for funding by the UN Capital Development Fund and UNDP.

Source: MINITRAPE, based in part on work done by CEAER, "Rapport d'Evaluation", Butare, 1985, and IPC, "Planung des Sonderenergieprogrammes Ruanda", 1986.

RWANDA: SELECTED MICRO-HYDRO SITES

Capacities and Costs

Site (River)	Commune	Prefecture	Flow (l/s)	Drop (m)	Power (kW)	Output (MWh)	Investment $'000	Investment $/kW	Ku	Annuity Factor	Other Charges	Cost/kWh US$	Cost/kWh RF
Mwange	Buyoga	Byumba	300	51	20	560	77	3,840	60%	0.1037	0.02	0.10	7.4
Mwanga	Gafunzo	Cyangugu	100	10	7	--	--	--	--	0.1037	--	--	--
Ntondwe	Karengera	Cyangugu	--	--	--	--	--	--	--	0.1037	--	--	--
Mwogo	Mudasomwa	Gikongoro	900	29	183	960	585	3,197	60%	0.1037	0.02	0.08	5.6
Simbuka	Nshili	Gikongoro	172	33	40	210	193	4,869	60%	0.1037	0.02	0.12	8.7
Cyimbili	Nyamyumba	Gisenyi	75	180	95	500	302	3,197	60%	0.1037	0.02	0.08	5.6
Pfunda	Nyamyumba	Gisenyi	400	12	34	180	148	4,367	60%	0.1037	0.02	0.11	7.9
Kiryango	Mukingi	Gitarama	367	17	44	230	214	4,858	60%	0.1037	0.02	0.11	8.6
Nazimeru	Nyakabanda	Gitarama	55	100	39	209	187	4,854	60%	0.1037	0.02	0.12	8.7
Buhari	Gishyita	Kibuye	81	135	77	400	250	3,263	60%	0.1037	0.02	0.08	5.8
Kagarama	Gishyita	Kibuye	110	44	34	186	166	4,894	60%	0.1037	0.02	0.12	8.8
Congori	Musasa	Kigali	100	50	28	150	136	4,846	60%	0.1037	0.02	0.12	8.8
Base	Nyamugali	Ruhengeri	180	25	30	160	144	4,800	60%	0.1037	0.02	0.12	8.7
Ruhurura	Nyamugali	Ruhengeri	45	30	10	--	--	--	--	--	--	--	--

Notes: Investment costs (based on 1985 information) have been adjusted by 28% as suggested by Colombani.
Ku = utilization of installed capacity.
Rate of interest: 10%.

Source: J. Colombani "Rapport de Mission Pré-Formulation/Faisabilité pour la Construction de Microcentrales Hydro-Electriques au Ruanda"; 1988.

RISK ASSESSMENTS FOR METHANE EXPLOITATION IN LAKE KIVU

1. Concerns have risen regarding environmental risks associated with large scale exploitation of the methane gas, ever since the pilot project at Cap Rubona was designed and built. The concerns basically grew after the Lake Nyos catastrophe. It may be worth reminding that this volcanic lake, located in Cameroon, was the place where nearly 2,000 people were killed after an enormous methane bubble came to the lake's surface and exploded into the atmosphere. The catastrophe took place in 1986 and caused great anxiety among people involved in similar projects. The fear of similar events occurring if increased exploitation of Lake Kivu's methane gas was to take place lead development agencies to commission specialized studies. The major study was performed by Haroun Tazieff, the then French Secretary of State for the Prevention of Major Risks.

2. The main risk identified to date is that the large scale extraction of the methane gas might alter the water circulation patterns in the Lake. As it is now, there is a very strong stratification that prevents vertical circulation of the waters. Sucking deep waters (where the methane gas is dissolved in large quantities) at a high rate might create imbalances and start a vertical circulation, possibly bringing large quantities of methane gas to/near the surface. These concerns have already caused the present methane gas producer to discharge used water deep into the Lake instead of at the surface, as short term financial considerations otherwise would have lead to. Whether this will be sufficient in the case of large scale exploitation was indeed the topic of the Tazieff report.

3. The conclusions of the report were rather optimistic: due to major differences in the Lake's history and morphology, the probability of experiencing the same disaster in Lake Kivu as in Lake Nyos would: (i) not be linked to the methane gas exploitation; and (ii) be very low and equal to that of any volcanic area in the world. The basis for this very assertive statement is that out of the two possible explanatory theories, the only one that fits the experience of Lake Nyos is that of a phreatic eruption. Consequently, the Tazieff report only recommends to build paraseismic features into the design standards of the future methane gas extraction plants at Lake Kivu.

6. However, other studies have identified other risks: for instance, the TECHNIP ENGINEERING study from 1986 concluded that three categories of risks exist in the Lake Kivu area:

(a) seismic risks;

(b) other natural risks; and

(c) industrial risks.

The major finding of the study is that the lack of detailed and homogeneous information on the Lake's environment makes it difficult to produce detailed recommendations. A list of required complementary studies is included in the study's report. This is a more all-embracing view of the potential risks involved and a logical consequence of this standpoint would be to make sure that an environmental impact assessment is carried out prior to any major investment.

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME

COMPLETED ACTIVITIES

Country	*Activity*	*Date*	*Number*
	SUB-SAHARAN AFRICA		
Africa Regional	Anglophone Africa Household Energy Workshop	07/88	085/88
	Regional Power Seminar on Reducing Electric Power System Losses in Africa	08/88	087/88
	Institutional Evaluation of EGL	02/89	098/89
	Biomass Mapping Regional Workshops	05/89	--
	Francophone Household Energy Workshop	08/89	103/89
	Interafrican Electrical Engineering College: Proposals for Short- and Long-Term Development	03/90	112/90
	Biomass Assessment and Mapping	03/90	--
Angola	Energy Assessment	05/89	4708-ANG
Benin	Energy Assessment	06/85	5222-BEN
Botswana	Energy Assessment	09/84	4998-BT
	Pump Electrification Prefeasibility Study	01/86	047/86
	Review of Electricity Service Connection Policy	07/87	071/87
	Tuli Block Farms Electrification Study	07/87	072/87
	Household Energy Issues Study	02/88	--
	Urban Household Energy Strategy Study	05/91	132/91
Burkina Faso	Energy Assessment	01/86	5730-BUR
	Technical Assistance Program	03/86	052/86
	Urban Household Energy Strategy Study	06/91	134/91
Burundi	Energy Assessment	06/82	3778-BU
	Petroleum Supply Management	01/84	012/84
	Status Report	02/84	011/84
	Presentation of Energy Projects for the Fourth Five-Year Plan (1983-1987)	05/85	036/85
	Improved Charcoal Cookstove Strategy	09/85	042/85
	Peat Utilization Project	11/85	046/85
Cape Verde	Energy Assessment	08/84	5073-CV
	Household Energy Strategy Study	02/90	110/90
Comoros	Energy Assessment	01/88	7104-COM
Congo	Energy Assessment	01/88	6420-COB
	Power Development Plan	03/90	106/90
Côte d'Ivoire	Energy Assessment	04/85	5250-IVC
	Improved Biomass Utilization	04/87	069/87
	Power System Efficiency Study	12/87	--
Ethiopia	Energy Assessment	07/84	4741-ET
	Power System Efficiency Study	10/85	045/85
	Agricultural Residue Briquetting Pilot Project	12/86	062/86
	Bagasse Study	12/86	063/86
	Cooking Efficiency Project	12/87	--
Gabon	Energy Assessment	07/88	6915-GA
The Gambia	Energy Assessment	11/83	4743-GM
	Solar Water Heating Retrofit Project	02/85	030/85
	Solar Photovoltaic Applications	03/85	032/85
	Petroleum Supply Management Assistance	04/85	035/85

Country	*Activity*	*Date*	*Number*
Ghana	Energy Assessment	11/86	6234-GH
	Energy Rationalization in the Industrial Sector	06/88	084/88
	Sawmill Residues Utilization Study	11/88	074/87
Guinea	Energy Assessment	11/86	6137-GUI
Guinea-Bissau	Energy Assessment	08/84	5083-GUB
	Recommended Technical Assistance Projects	04/85	033/85
	Management Options for the Electric Power and Water Supply Subsectors	02/90	100/90
	Power and Water Institutional Restructuring (French)	04/91	118/91
Kenya	Energy Assessment	05/82	3800-KE
	Power System Efficiency Study	03/84	014/84
	Status Report	05/84	016/84
	Coal Conversion Action Plan	02/87	--
	Solar Water Heating Study	02/87	066/87
	Peri-Urban Woodfuel Development	10/87	076/87
	Power Master Plan	11/87	--
Lesotho	Energy Assessment	01/84	4676-LSO
Liberia	Energy Assessment	12/84	5279-LBR
	Recommended Technical Assistance Projects	06/85	038/85
	Power System Efficiency Study	12/87	081/87
Madagascar	Energy Assessment	01/87	5700-MAG
	Power System Efficiency Study	12/87	075/87
Malawi	Energy Assessment	08/82	3903-MAL
	Technical Assistance to Improve the Efficiency of Fuelwood Use in the Tobacco Industry	11/83	009/83
	Status Report	01/84	013/84
Islamic Republic of Mauritania	Energy Assessment	04/85	5224-MAU
	Household Energy Strategy Study	07/90	123/90
Mauritius	Energy Assessment	12/81	3510-MAS
	Status Report	10/83	008/83
	Power System Efficiency Audit	05/87	070/87
	Bagasse Power Potential	10/87	077/87
Mozambique	Energy Assessment	01/87	6128-MOZ
	Household Electricity Utilization Study	03/90	113/90
Niger	Energy Assessment	05/84	4642-NIR
	Status Report	02/86	051/86
	Improved Stoves Project	12/87	080/87
	Household Energy Conservation and Substitution	01/88	082/88
Nigeria	Energy Assessment	08/83	4440-UNI
Rwanda	Energy Assessment	06/82	3779-RW
	Energy Assessment	07/91	8017-RW
	Status Report	05/84	017/84
	Improved Charcoal Cookstove Strategy	08/86	059/86
	Improved Charcoal Production Techniques	02/87	065/87
Sao Tome and Principe	Energy Assessment	10/85	5803-STP

Country	*Activity*	*Date*	*Number*
Senegal	Energy Assessment	07/83	4182-SE
	Status Report	10/84	025/84
	Industrial Energy Conservation Study	05/85	037/85
	Preparatory Assistance for Donor Meeting	04/86	056/86
	Urban Household Energy Strategy	02/89	096/89
Seychelles	Energy Assessment	01/84	4693-SEY
	Electric Power System Efficiency Study	08/84	021/84
Sierra Leone	Energy Assessment	10/87	6597-SL
Somalia	Energy Assessment	12/85	5796-SO
Sudan	Management Assistance to the Ministry of Energy and Mining	05/83	003/83
	Energy Assessment	07/83	4511-SU
	Power System Efficiency Study	06/84	018/84
	Status Report	11/84	026/84
	Wood Energy/Forestry Feasibility	07/87	073/87
Swaziland	Energy Assessment	02/87	6262-SW
Tanzania	Energy Assessment	11/84	4969-TA
	Peri-Urban Woodfuels Feasibility Study	08/88	086/88
	Tobacco Curing Efficiency Study	05/89	102/89
	Remote Sensing and Mapping of Woodlands	06/90	--
	Industrial Energy Efficiency Technical Assistance	08/90	122/90
Togo	Energy Assessment	06/85	5221-TO
	Wood Recovery in the Nangbeto Lake	04/86	055/86
	Power Efficiency Improvement	12/87	078/87
Uganda	Energy Assessment	07/83	4453-UG
	Status Report	08/84	020/84
	Institutional Review of the Energy Sector	01/85	029/85
	Energy Efficiency in Tobacco Curing Industry	02/86	049/86
	Fuelwood/Forestry Feasibility Study	03/86	053/86
	Power System Efficiency Study	12/88	092/88
	Energy Efficiency Improvement in the Brick and Tile Industry	02/89	097/89
	Tobacco Curing Pilot Project	03/89	UNDP Terminal Report
Zaire	Energy Assessment	05/86	5837-ZR
Zambia	Energy Assessment	01/83	4110-ZA
	Status Report	08/85	039/85
	Energy Sector Institutional Review	11/86	060/86
	Power Subsector Efficiency Study	02/89	093/88
	Energy Strategy Study	02/89	094/88
	Urban Household Energy Strategy Study	08/90	121/90
Zimbabwe	Energy Assessment	06/82	3765-ZIM
	Power System Efficiency Study	06/83	005/83
	Status Report	08/84	019/84
	Power Sector Management Assistance Project	04/85	034/85
	Petroleum Management Assistance	12/89	109/89
	Power Sector Management Institution Building	09/89	--
	Charcoal Utilization Prefeasibility Study	06/90	119/90

Country	*Activity*	*Date*	*Number*
	ASIA AND THE PACIFIC		
Asia Regional	Pacific Household and Rural Energy Seminar	11/90	--
Bangladesh	Energy Assessment	10/82	3873-BD
	Priority Investment Program	05/83	002/83
	Status Report	04/84	015/84
	Power System Efficiency Study	02/85	031/85
	Small Scale Uses of Gas Prefeasibility Study	12/88	--
China	County-Level Rural Energy Assessments	05/89	101/89
	Fuelwood Forestry Preinvestment Study	12/89	105/89
Fiji	Energy Assessment	06/83	4462-FIJ
India	Opportunities for Commercialization of Nonconventional Energy Systems	11/88	091/88
	Bagasse Cogeneration Preinvestment Study	07/90	120/90
Indonesia	Energy Assessment	11/81	3543-IND
	Status Report	09/84	022/84
	Power Generation Efficiency Study	02/86	050/86
	Energy Efficiency in the Brick, Tile and Lime Industries	04/87	067/87
	Diesel Generating Plant Efficiency Study	12/88	095/88
	Urban Household Energy Strategy Study	02/90	107/90
	Biomass Gasifier Preinvestment Study Vols. I & II	12/90	124/90
Malaysia	Sabah Power System Efficiency Study	03/87	068/87
Myanmar	Energy Assessment	06/85	5416-BA
Nepal	Energy Assessment	08/83	4474-NEP
	Status Report	01/85	028/84
Papua New Guinea	Energy Assessment	06/82	3882-PNG
	Status Report	07/83	006/83
	Energy Strategy Paper	--	--
	Institutional Review in the Energy Sector	10/84	023/84
	Power Tariff Study	10/84	024/84
Solomon Islands	Energy Assessment	06/83	4404-SOL
South Pacific	Petroleum Transport in the South Pacific	05/86	--
Sri Lanka	Energy Assessment	05/82	3792-CE
	Power System Loss Reduction Study	07/83	007/83
	Status Report	01/84	010/84
	Industrial Energy Conservation Study	03/86	054/86
Thailand	Energy Assessment	09/85	5793-TH
	Rural Energy Issues and Options	09/85	044/85
	Accelerated Dissemination of Improved Stoves and Charcoal Kilns	09/87	079/87
	Northeast Region Village Forestry and Woodfuels Preinvestment Study	02/88	083/88
	Impact of Lower Oil Prices	08/88	--
	Coal Development and Utilization Study	10/89	--
Tonga	Energy Assessment	06/85	5498-TON
Vanuatu	Energy Assessment	06/85	5577-VA
Western Samoa	Energy Assessment	06/85	5497-WSO

Country	Activity	Date	Number
	EUROPE, MIDDLE EAST AND NORTH AFRICA (EMENA)		
Morocco	Energy Assessment	03/84	4157-MOR
	Status Report	01/86	048/86
Pakistan	Household Energy Assessment	05/88	--
	Assessment of Photovoltaic Programs, Applications, and Markets	10/89	103/89
Portugal	Energy Assessment	04/84	4824-PO
Syria	Energy Assessment	05/86	5822-SYR
	Electric Power Efficiency Study	09/88	089/88
	Energy Efficiency Improvement in the Cement Sector	04/89	099/89
	Energy Efficiency Improvement in the Fertilizer Sector	06/90	115/90
Tunisia	Fuel Substitution	03/90	--
Turkey	Energy Assessment	03/83	3877-TU
Yemen	Energy Assessment	12/84	4892-YAR
	Energy Investment Priorities	02/87	6376-YAR
	Household Energy Strategy Study Phase I	03/91	126/91
	LATIN AMERICA AND THE CARIBBEAN (LAC)		
LAC Regional	Regional Seminar on Electric Power System Loss Reduction in the Caribbean	07/89	--
Bolivia	Energy Assessment	04/83	4213-BO
	National Energy Plan	12/87	--
	La Paz Private Power Technical Assistance	11/90	111/90
	Natural Gas Distribution	03/91	125/91
	Prefeasibility Evaluation Rural Electrification and Demand Assessment	04/91	129/91
Chile	Energy Sector Review	08/88	7129-CH
Colombia	Energy Strategy Paper	12/86	--
Costa Rica	Energy Assessment	01/84	4655-CR
	Recommended Technical Assistance Projects	11/84	027/84
	Forest Residues Utilization Study	02/90	108/90
Dominican Republic	Energy Assessment	05/91	8234-DO
Ecuador	Energy Assessment	12/85	5865-EC
	Energy Strategy Phase I	07/88	--
	Energy Strategy	04/91	--
Haiti	Energy Assessment	06/82	3672-HA
	Status Report	08/85	041/85
Honduras	Energy Assessment	08/87	6476-HO
	Petroleum Supply Management	03/91	128/91
Jamaica	Energy Assessment	04/85	5466-JM
	Petroleum Procurement, Refining, and Distribution Study	11/86	061/86
	Energy Efficiency Building Code Phase I	03/88	--
	Energy Efficiency Standards and Labels Phase I	03/88	--
	Management Information System Phase I	03/88	--
	Charcoal Production Project	09/88	090/88
	FIDCO Sawmill Residues Utilization Study	09/88	088/88
Panama	Power System Efficiency Study	06/83	004/83

Country	*Activity*	*Date*	*Number*
Paraguay	Energy Assessment	10/84	5145-PA
	Recommended Technical Assistance Projects	09/85	--
	Status Report	09/85	043/85
Peru	Energy Assessment	01/84	4677-PE
	Status Report	08/85	040/85
	Proposal for a Stove Dissemination Program in the Sierra	02/87	064/87
	Energy Strategy	12/90	--
Saint Lucia	Energy Assessment	09/84	5111-SLU
St. Vincent and the Grenadines	Energy Assessment	09/84	5103-STV
Trinidad and Tobago	Energy Assessment	12/85	5930-TR

GLOBAL

	Energy End Use Efficiency: Research and Strategy	11/89	--
	Women and Energy--A Resource Guide The International Network: Policies and Experience	04/90	--

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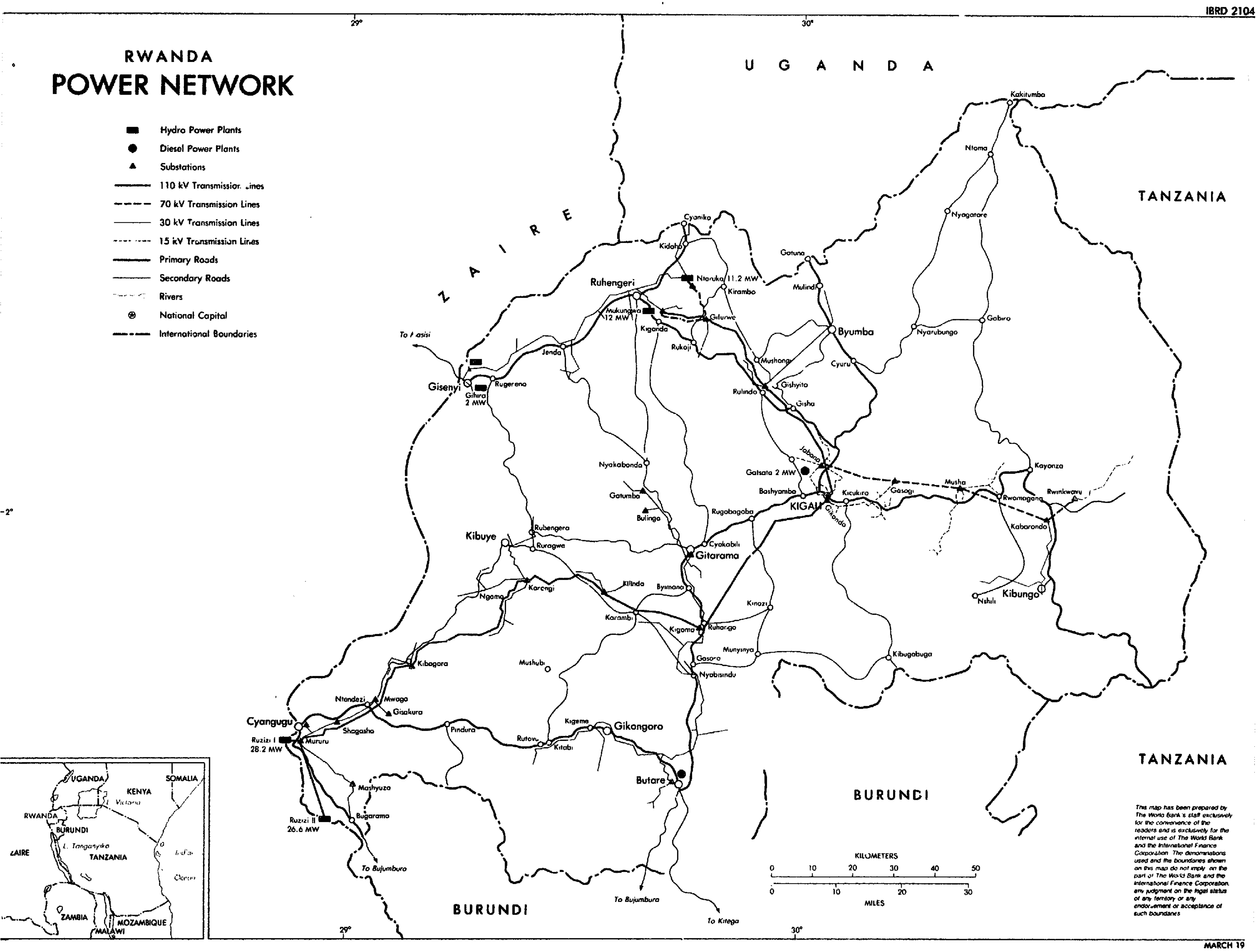
IBRD 2104
RWANDA
POWER NETWORK
Hydro Power Plants
Diesel Power Plants
Substations
110 kV Transmission Lines
70 kV Transmission Lines
30 kV Transmission Lines
15 kV Transmission Lines
Primary Roads
Secondary Roads
Rivers
National Capital
International Boundaries
UGANDA
ZAIRE
TANZANIA
BURUNDI
Kakitumba
Ntoma
Nyagatare
Gabiro
Nyarubungo
Gatuna
Mulindi
Byumba
Cyuru
Cyanika
Kidaho
Ntaruka 11.2 MW
Kirambo
Ruhengeri
Mukungwa 12 MW
Kiganda
Gifurwe
Rukoji
Mushongi
Gishyita
Rulindo
Gisha
Jenda
Gisenyi
Rugerero
Gihira 2 MW
Nyakabonda
Gatumba
Bulinga
Jabana
Gatsata 2 MW
Bashyamba
KIGALI
Gikondo
Kicukiro
Gasogi
Musha
Kayonza
Rwamagana
Rwinkwavu
Kabarondo
Kibungo
Nshili
Rugobagoba
Cyakabili
Gitarama
Kibuye
Rubengera
Ruragwe
Karengi
Ngoma
Kilinda
Byimana
Kinazi
Karambi
Kigoma
Ruhango
Munyinya
Kibugabuga
Gasoro
Nyabisindu
Mushubi
Kibogora
Ntendezi
Mwaga
Gisakura
Cyangugu
Shagasha
Ruzizi I 28.2 MW
Mururu
Pindura
Rutovu
Kitabi
Kigeme
Gikongoro
Butare
Mashyuza
Bugarama
Ruzizi II 26.6 MW
To Bujumbura
To Kitega
To Masisi
KILOMETERS
0 10 20 30 40 50
0 10 20 30
MILES
29°
30°
2°
UGANDA
KENYA
SOMALIA
RWANDA
BURUNDI
ZAIRE
TANZANIA
ZAMBIA
MOZAMBIQUE
MALAWI
L. Victoria
L. Tanganyika
Indian Ocean
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MARCH 19