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ENERGY IN RWANDA - A SYNOPSIS

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INTRODUCTION

The purpose of this study is to synthesise the information available on the current energy situation in Rwanda. An examination of the available documentation was made and discussions were held with persons involved in the energy sector. This report is a synopsis of the information thus obtained.

The report is divided into five sections, of which the first two examine the current most widely-used sources of energy: wood and hydro-electric power. The third and fourth sections consider the two most important potential sources : methane gas and peat. Finally, the last section is devoted to smaller new or renewable energy sources such as solar power and biomass. The past and planned future developments of these resources are described, including supply and demand estimates where possible. The influence of Government policy and foreign aid donors is also given consideration. An annex to the report briefly treats the question of imported fuels and their substitutability with indigenous energy sources.

In view of the fact that this is a general summary, rather than a detailed technical report, a complete list of sources is given at the end of the report through which more detailed technical information can be obtained. An addendum to this list gives additional sources which should become available in the next 6-8 months.

I. WOOD AND CHARCOAL

In Rwanda, as in most African countries, wood is by far the most widely used source of energy for domestic purposes. Its primary use is for cooking, although it is also used for heating in high altitudes. In view of its importance in the everyday life of the Rwandan population and the fact that a supply problem has been known to exist for decades, it is surprising that so little research has been carried out on the availability, uses and consevation of wood. The existence of a problem was recognised at least as early as 1920 when the Belgian authorities supervised the planting of 380 hectares. Since then intermittent efforts at reforestation have been made, with 10,000 hectares planted between 1931 - 1938 alone. However, progress halted abruptly during the Second World War, and the situation has deteriorated considerably, particularly in the past two decades, despite efforts by the Ministry of Agriculture and various foreign aid projects to reforest new areas.

At the National level the administrative responsibility for forestry development lies with the Department of Water and Forests in the Ministry of Agriculture, while at the commune level agronomists are responsible for the technical aspects of forestry resource development and the bourgmaster has administrative authority over commune woodlots.

Supply and demand

The supply of wood in 1977 was estimated as between 100-130,000 hectares of natural forest, and 25-26,000 hectares of planted woodlots. (1) The forested area is mainly comprised of the Gishwati and Nyungwe natural forests which, according to MINAGRI statistics, declined in area from 162,000 hectares in 1957 to 130,000 hectares in 1977, i.e. 1600 hectares per annum.

(1) WB study - 100,000 ha forest and 26,000 planted woodlots.
Minagri - 130,000 ha forest, 25,000 planted

This drastic reduction in the area forested was accompanied by further cutting within the forests. In addition to these two forests a third area of natural woodland is located in Bugesera in southern Rwanda. This has been a major charcoal producing area, supplying Kigali and other urban markets.[1] However, in two of the three Bugesera communes the wooded area has now been almost completely destroyed and in the third it is rapidly being depleted.

Of the planted woodlands, the vast majority, amounting to 60 - 70% of the total area, is owned by the communes. A further 15 - 20% belongs to individuals or private groups, 10% is state land, and 2% is roadside planting. The commune woodlands are made up of approximately 5,000 lots, of which 2,300 are smaller than two hectares and only about 500 are over 10 hectares.

The rapid diminution in the area of wooded land, particularly in Bugesera and the Nyungwe and Gishwati forests indicates that the demand for wood far exceeds the supply available through natural regeneration. This contention is supported by recent estimates that demand per person ($1m^3$) is equal to the natural regeneration rate of .1 hectare, while actual forested area is .04 hectare per person. In other words, the forested area is equal to only 40% of the area which would be required to fulfil the demand by natural regeneration.

Even with the depletion of woodlands and forests, there remains a deficiency in the supply which is filled by the use of dried manure and vegetable matter with consequent reduction in soil fertility, and by imports of wood from Zaire, Uganda and Tanzania.

1. The manufacture of charcoal requires 4 kg of wood for every 1 kg of charcoal produced. The process involves cutting the trees and drying them for 10 days. They are then reduced to two to three meter lengths, and arranged in piles, with branches filling in gaps.
The piles of wood are covered by a layer of mud, then a layer of weeds and grass, and finally another layer of wood. Openings are left in this cover to introduce live charcoals and the wood is burnt for 6 to 7 days. On the 6th day, the smell and colour of the smoke indicate whether or not the process is terminated. The oven is then dismantled, the charcoal spread out to cool and later put in sacks and transported to the market.

Charcoal

A relatively large component of the total demand for wood is derived from the Kigali charcoal market. It has been estimated that the annual consumption of charcoal in Kigali is 63,000 sacks (of approx.50 - 60 kg) for which 780 hectares must be deforested. Most of this wood comes from the Bugesera reserve. According to a recent survey, 95% of Kigali households use charcoal for cooking. There is also a fairly high industrial demand for charcoal to be used in processes such as firing bricks and tiles and in traditional forges. It is preferable to wood because of its higher calorific value and because it produces less smoke and cinders.

The deforestation of the Bugesera region to provide charcoal for Kigali, and other urban markets, was exacerbated by immigration into the region and consequent burning of large tracts to clear land, eradicate tse-tse flies, and generate new growth for livestock grazing. The rate of influx of settlers into the region, as a result of economic and political factors, is reflected in the change of population density from 20 persons per Km^2 in 1960 to 120 persons per Km^2 in 1978.

GOR Policy

In recent years, and particularly since 1978, the government has attempted to implement a forestry management policy which takes into account the state, communal and private woodlots, as well as the natural forests.

In the natural forests there has been a drive to replant areas between the actual boundaries of the forested area and the official boundaries. Where these areas had already been settled, families were in some cases relocated. In other cases this was not possible. Both in the natural forests and in the state woodlands guards are employed by the government to control cutting activities.

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II. HYDRO-ELECTRIC POWER

Introduction

Hydro-electric power is the primary source of energy for Rwanda's industries, administrative sector and a small part of the urban population. Although hydro-power has been exploited since the 1950's, it is only recently that the network has been extended to include most of the major towns. Production is increasing at an average 10% - 13% p.a - a trend which is likely to continue for at least the next decade in view of the fact that imported subsitutes (e.g. diesel) are extremely expensive, and local substitutes such as methane gas or solar energy are still at a very early stage of development.

Production

The majority of Rwanda's hydro-electric power is presently supplied by two main stations, with a third to open in Dec. 81. By far the largest supplier in 1980 was Ruzizi I jointly owned by Rwanda, Burundi and Zaire, (28.2 MW) which satisfied 66.5% of Rwanda's total consumption. This plant is located 5km from Lake Kivu on the frontier with Zaire, and supplies the Katana region of Zaire as well as Rwanda.

The second major supplier is the Ntaruka station (11.25 MW) between Lake Ruhondo and Lake Bulera in Ruhengeri. In 1980, 30% of Rwanda's total consumption came from here. This station reached maximum capacity in 1969 and due to a decline in the level of Lake Bulera annual production has since decreased. A twin station to Ntaruka, Mukungwa, which will have an estimated annual output of 48 GWH, over twice that of Ntaruka, is almost completed on Lake Ruhondo and will open in late 1981.

Several smaller stations complete the inventory. The Gisenyi hydro-electric station which began production in 1958 was out of operation during 1979 and a part of 1980 but reopened in December 1980 and will produce about 6GWH in 1981.

This station supplies the town of Gisenyi, the Nyundo mission and Bralirwa, as well as part of the town of Goma in Zaire. Two other plants, one near Ruhengeri and one near Gisenyi, are privately owned and have very low production levels.

In addition to these hydro-electric stations, numereous diesel powered generators have supplemented the supply of electric power in Rwanda. This source of energy is declining in importance as the cheaper hydro-power is more widely distributed. The percentage of electricity generated by diesel declined from 12.8% in 1967 to 2% in 1980.

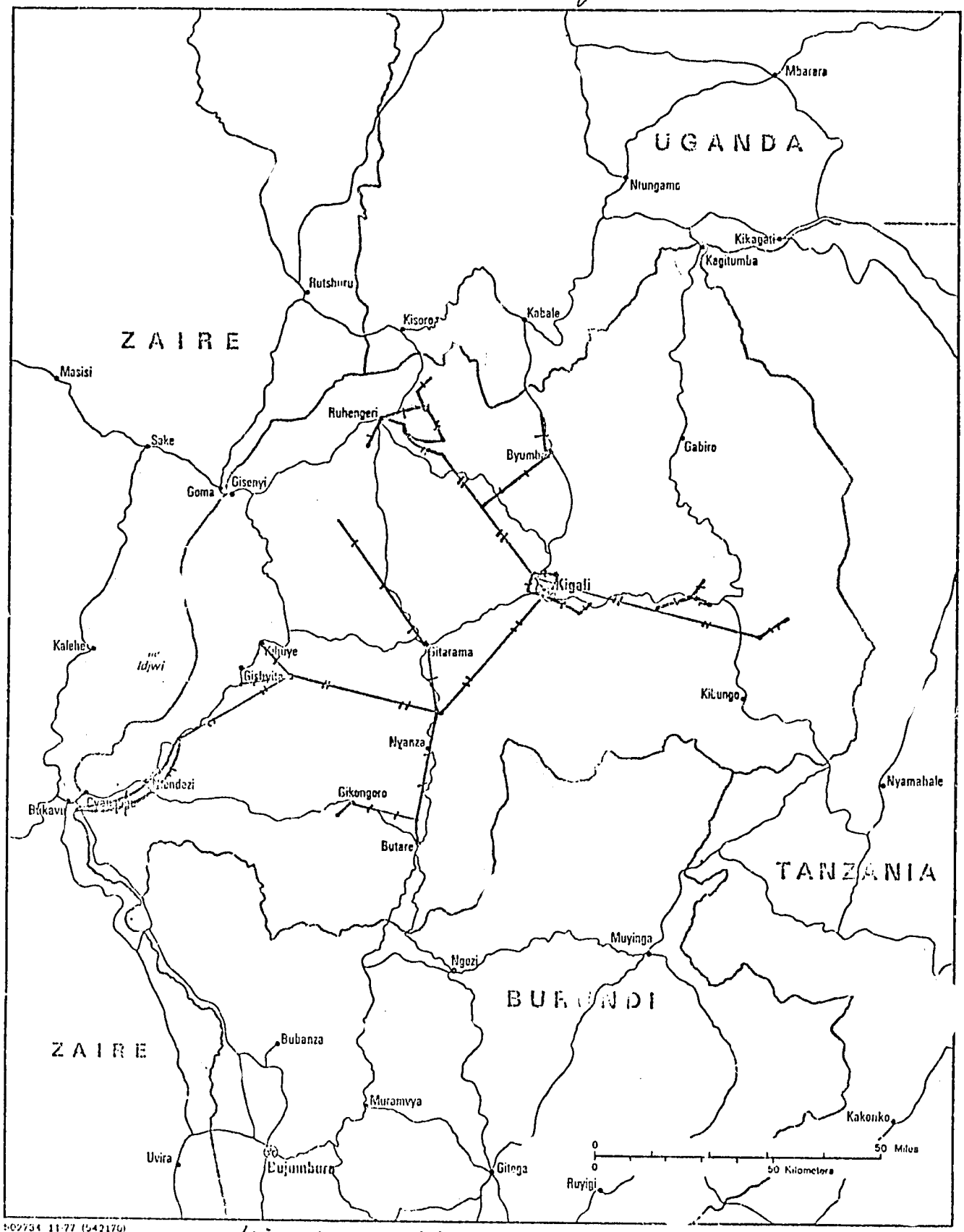
Distribution

The present distribution system relies on two high-tension lines; one (123 Km) from Ntaruka to Kigali and into the mines of Rutongo, Musha, Rwinkwavu and Bugarama, and the other, (185 Km) linking Ruzizi with Kigali.(1)

Several medium-tension lines extend this network to major urban centers. On the Ruzizi-Kigali line there is a link from Kigoma to Butare and Gikongoro, and another from Kigoma to Gitarama & Gatumba. There are several shorter MT lines linking Ruhengeri, Kibuye, Ngoma, Byumba & Mulindi with the MT network. Thus 8 of the 10 major towns (prefectural centers) are supplied by this system. Gisenyi has its own station, and a MT line linking it to Ruhengeri is planned. Kibungo is presently supplied by diesel-generated power, but Belgian funding has been obtained for a MT line linking it with the major MT network.

(1) See map attached.

Rwanda - Sketch of the electricity distribution network.



502734 11-77 (542170)
Mercator Projection
Scale 1:1,000,000

High tension lines - 110 - 70 kv.

Medium tension lines - 30 - 15 kv

Road

Airport

Present Supply and Demand

The potential and actual supply (in GWH) of hydro-power available to Rwanda in 1980 is shown below:

SOURCE	POTENTIAL SUPPLY	ACTUAL SUPPLY
RUZIZI I	160 (2)	44.8
NTARUKA	22	20.5
GISENYI	5.4	.7 (3)
	133.4 (1)	66.0 (4)

Source: Ministry of Natural Resources, Water and Energy Section, 3rd 5-year Plan, June 1981.

Given a transmission loss of 10% and assuming Rwanda's share of Ruzizi I to be 53 GWH (5) it can be seen that there is little margin between the potential and actual supply.

Effective demand for electricity is heavily concentrated geographically and sectorally. Major consumers include the mines and tea factories, the service sector (administration buildings and hospitals) infrastructure (radio relay station, roads & airport) and private consumers and commercants in Kigali. Kigali consumption is approximately 65% of total consumption in the country.

Future Supply and Demand

The production & annual rate of increase over the past 5 years is shown below:

	76	77	78	79	80
PROD. (GWH)	40.4	45.7	48.4	53.3	59.6
RATE OF INC. (%)		13%	5.8%	10.2%	11.7%

(1) Total supply - i.e. including energy available to Zaire and Burundi
(2) This figure was given by Electrogaz. The Ministry of Natural Resources figure was 106.
(3) Out of operation for part of this year
(4) An additional 1.4 Kwh supplied by diesel brings 1980 total production to 67.4.
(5) Although Rwanda is officially entitled to only 33% of available energy from Ruzizi I, it actually uses more & will certainly continue to do so as long as demand from Zaire and Burundi remains below their entitlement.

Assuming an annual increase in demand for energy of 11.7% [1] the needs over the next 5 years will be as follows:

	1980	81	82	83	84	85	86
Demand	59.6	66.6	74.4	83.1	92.2	103	115

The present supply of approximately 80 GWH will be increased at the end of 1981 by the new station at Mukungwa (12 MW) which will have a potential annual output of 45 GWH [2], thus increasing the total supply to 125 GWH. Allowing for 10% loss in transmission and distribution this will be insufficient by 1986.

Total supply will be further increased by Ruzizi II, which should be operational in 1985. The output of this station is uncertain because the flow over the past 20 years has been considerably greater than it was over the previous 20, and if this trend continues output will be considerably increased. Present estimates are for an annual output of between 140-200 GWH. This power station will supply Zaire as well as Rwanda and will be managed along with Ruzizi I by a yet-to-be-formed power board consisting of representatives of the countries concerned.

Also planned to start production in 1985 is the Gihira station (Gisenyi II) with an estimated output of 15 GWH per year. The other major new source of energy is Rusumo on the Tanzanian border, planned to come into production in the 1990's with a capacity of 100 MW.

Even with supplies from Ruzizi II, it is probable that by the mid 1990's Rwanda will be relying on electrical energy from the Rusumo falls project.

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(1) Ministry of Natural Resources estimate

(2) Tractionel study

SMALL HYDROPOWER SCHEMES

Efforts to exploit hydro-power in Rwanda have been focused on the development of large hydro-electric stations and the extension of the distribution network. Since small hydropower schemes would provide relatively insignificant quantities to the overall supply, they have only received cursory attention. However, the potential exists for the development of localised small schemes where a suitable waterfall is situated in proximity to a commercial center, service center or other area of concentrated demand. Several specific sites have been suggested. The 1967 Lahmeyer report proposed 10 sites with potential of from .10 MW to 2.8 MW, and of these, four were considered economically feasible by the 1980 Klock report. All the sites are located in western, or south western Rwanda. This is the area of the Zaire Nile crest where rainfall is high (at least 1200 MW p.a. required) and where suitable waterfalls exist.
The smallest, Nkora site (1. MW) has a hydropower station which is at present in a state of disrepair, but which can be made functional by a relatively minor investment ($10,000 - $15,000). As will be the case with any small hydropower scheme, maintenance is a major problem.

The construction costs of the other three stations Akanyaru II (2.7 MW) Karundure (2.5 MW) and Kamiranzovu (1.1 MW) are estimated at $3.7 million, $2.4 million, and $1.6 - 2.2 million respectively, including the cost of transmission lines.

A study presently being undertaken by Swiss aid is examining the question of small hydro-power schemes in more detail and the results should be available in April 1982.

Donors

Up to now the F.E.D. has been the principal donor ($16 million) partially financing the Mukungwa station and a number of HT & MT lines and studies. The BADEA ($9 million) has also financed equipment for Mukungwa, and Swiss, German and Belgian aid have financed studies & extensions of the distribution network.

Other interested donors include the BAD, and French aid. A meeting is scheduled for early 1982 at which it is hoped firm commitment will be made by donors to finance the extension of the present distribution network.

GOR Policy

The development of hydro-power resources, including planning, obtaining financing, and developing policy is the responsibility of the Ministry of Natural Resources. The actual management and maintenance of installed stations is performed by the parastatal "ELECTROGAZ".

The exploitation of hydro-electric power is strongly supported by the Government. In the past, priority was given to the construction of large power plants, but more recently the Governement has expressed a desire to develop smaller hydro-power plants serving localised needs. As far as distribution is concerned, proposals have been drawn up by the Government for approximately 30 new MT extension lines for which financing is being sought.

GOR policy regarding power to be used for industries related to the methane gas in Lake Kivu, could have a profound effect on the energy situation. Official policy is that the heavy industries envisioned, e.g. production of urea fertiliser or methanol, which have high energy demands must use hydro-electric power for the transformation processes. If these industries are developed in the next 5-10 years there could be problems ensuring adequate energy supplies.

Conclusion

Hydro-electric power is, and will continue to be, the major source of energy for Rwanda's industries, the public sector, prefectural centres, and other towns near the major distribution network.

However, the scattered settlement pattern in Rwanda renders widespread household use of electricity out of the question in the near future. In some areas of western Rwanda it may be economically viable to exploit mini-hydro-electric schemes. This is not possible for eastern and part of central Rwanda which must rely on connections with the national network. Even

in the western area it is generally more economic for areas within 10-15 kms of an MT line to be connected to that line rather than to be served by a mini-power station. For those areas of consumption distant from the existing network, potential small hydro-power sources will have to be examined individually in order to ascertain their technical and economic feasibility.

Decisions on the development of small stations require a more comprehensive inventory that has been done to date. This should be available from Swiss aid in April 1982. In addition the considerable economic and non-economic indirect benefits of rural electrification such as its contribution to counteracting rural-urban migration must be taken into account.

III. METHANE GAS

I. Background

Since the discovery of methane gas in Lake Kivu in 1936 a large number of scientific & technical studies have been carried out with financing from Belgium, Germany, the U.N. (UNIDO) and the U.S. (Woods Hole Oceanographic Institute). These studies indicate the existence of 50 - 60,000 million cubic meters (Nm^3) of methane gas, at depths of approximately 300 - 500 meters, in water which, though warmer than surface water is more dense due to a high level of salinity. There is no conclusive evidence on the origin of the gas, though it is generally believed to result from biological rather than chemical activity(1), and to be renewable.

II. Exploitation of the Resource

The exploitation of methane gas has been retarded by several factors. Firstly, despite numerous studies, there remain very many unresolved technical and scientific problems. Secondly, effective, (as opposed to potential) energy demand in the region is very weak. And thirdly, there are problems arising from the fact that the resource is jointly owned by Zaire and Rwanda.

The only existing project is a small extraction plant, built by Belgium in 1962, at Cap Rubona, 8 km south-east of Gisenyi. This was originally intended to be a 5-year pilot project, but actually functioned for 10 years relatively efficiently and for another 2-4 intermittently. Since 1977 it has been under repair (with U.N. financing) and it is due to reopen in December 1981.

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(1) Bacterial decomposition of plankton, rather than thermocatalitic activity - may be a combination of the two.

The de- gassed, but otherwise untreated saline waters are returned to the surface of the lake. The gas, which is then composed of 24.9% methane (CH_4) and 73.5% carbon dioxide (CO_2) as well as some inert gases, is purified, mainly by removal of the CO_2 to a 70-80% methane content. Water used in this process and containing the excess CO_2 flows onto the surface of the lake. The ecological effects of this are unknown.

Uses of the Resource

At present the methane gas is only used to provide power for the Bralirwa brewery in Gisenyi. The gas is compressed at Cap Rubona and pumped through a 3 km pipeline to the brewery, which is the only potential customer within 10 kms. Because of the absence of alternative buyers the UN required a guarantee that Bralirwa would purchase the gas, before financing a renovation of the plant. Although methane was previously sold at a price comparable to gasoline, future sales will be at a more favourable rate (though still covering costs) to take into account the relative inconvenience of using methane i.e. variations in the quantity and quality of gas supplied.

Potential uses

The uses of the gas depend to a large extent on the form in which it is produced. There are 3 main possibilities.

1. Gas which is to be used without further transformation. This must be compressed or liquified in order to be stored or transported. Compressed gas requires extremely heavy containers and is thus difficult and expensive to transport. The major problem with storing and transporting liquified gas is the need to maintain extremely low temperatures (between -82.5^{o} and -161.5^{o}). Because of these problems the gas extraction plant would have to be located near areas of gas consumption.

Two major potential users of methane gas were identified in a 1980 market study carried out by SAARBERG-INTERPLAN. Both of these are located in Zaire. The first is the Katana Cement factory which has not been functioning since 1962, (apparently due to problems working under the Government of Zaire official price policy), but which, if renovated and reopened could absorb up to 16 million m^3 of gas per year with 80% methane content.

If the obstacle of official prices could be overcome, gas could be sold at .46Z/m^3 and still be competitive with the presently proposed alternative energy resource - a mixture of peat (from Cyangugu) and diesel (1). Present plans however envisage the reopening of this plant in early 1982 using the latter source of energy.

The second potential user is the Pharmakina (quinine treatment) enterprise at Bukavu which would take 375-600,000 m^3 per year. The energy resources presently used by Pharmakina are diesel and wood, at an estimated cost of 190,500 Zaires per year. To be competitive, methane gas would have to be sold at approximately .46 Zaires/m^3 delivered at the factory.

In addition to the above-mentioned existing projects there are proposals for 2 new projects which would be potential users of methane gas. The first is for a plant to extract quinine in Rwanda - this would have a very low demand - and the second is for a proposed industrial zone to be developed in the neighbourhood of the Katana cement factory in Zaire.

2. A more expensive, but more versatile source of energy is obtained by transforming methane gas into methanol. This could be used to partially replace gasoline imports by mixing up to 15% of methanol with gasoline. This mixture can only be made with heavy, high octane fuels and there is some dispute as to whether the quality is equal to that of pure gasoline. There are also unresolved technical problems such as decomposition of the mixture in presence of water. Unless there is an extremely high increase in the price of gasoline this is probably not a realistic proposition.

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(1) See SAARBERG-INTERPLAN pp. 4-88-92 for more detailed analysis. Initial cost estimates indicate that this price would be economically feasible for an intermediate-sized plant.

Methanol could replace diesel for vehicular or industrial use, but this would require adapting motors, boilers, etc. for methanol combustion. It is also possible to transform methanol into gasoline, but again this would be a very costly product, and the technology is still in the experimental stages. (1)

The major potential industrial users in Rwanda would be the proposed cement factory in Cyangugu (at the moment it is planned to use diesel) and the proposed Kigali Brewery (for which electricity is foreseen.

In Zaire, the Katana cement factory could use methanol as an alternative to peat, or methane gas,and the Pharmakina plant could use it as a substitute for wood/diesel or methane. As mentioned earlier, neither of these eventualities are likely.

Households might be potential consumers for cooking and lighting but there are many problems including the high toxidity of methanol, the fact that it is an unknown product, that new stoves would have to be made and that no commercialization system exists.

3. Methane gas can be used to produce urea-based fertilizer particularly suitable for export crops. However, the urea must be used in combination with other chemicals including potash which is not known to be available in Rwanda or the surrounding area. The percentage of urea that can be used varies from 50% for coffee to approximately 20% for food crops. Effective demand for fertiliser is presently very weak in Rwanda (647 tons imported in 1980) as well as Burundi (2144 tons imported in 1978), and is mainly confined to export enterprises such as OCIR. No figures are available for demand in Zaire, but extension of land area, rather than more intensive cultivation is possible there. Constraints on the marketing of fertiliser include lack of purchasing power among small farmers and ignorance on the correct use of the fertiliser, as well as lack of information on the requirements of different soil types within Rwanda, and the absence of a suitable distribution & storage system.

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(1) An entrepreneur in California recently opened a methanol station. He has sold several hundred vehicles fueled by methanol and charges $ 800- $ 1,000 to transform a gasoline engine to run on methanol.

(2) The status of this project is uncertain.

Donor Agency Contributions

Several countries are presently interested in implementing projects to extract and transform methane gas.

Belgium has completed a pre-feasibility study on a methanol plant and is planning to provide 25% financing for a $50,000,000 plant to extract and transform methane gas into methanol. The proposed capacity of this plant (30 million m^3 per year) will be 15 times greater than the existing Cap Rubona plant. It is estimated that the price of methanol will be competitive with that of peat. Proposed uses of the methanol are for vehicles and cooking stoves but details of the marketing & distribution sytems have not yet been worked out. A pre-feasibility study of a fertiliser plant is also being undertaken.

The U.N., in addition to financing and supervising the renovation of the Cap Rubona gas extraction plant, is presently studying a project to dry the residue of malt & yeast from the Bralirwa brewery in order to produce animal feed. This project would be financed by UNCDF & supervised by FAO technical assistance. The animal feed produced would satisfy 80% of the total food needs of the FAO livestock breeding project at Kabuye. The major cost of this project is derived from the high energy requirements to dry the brewery wastes which have an initial 80% water content. AIDR is studying the possibility of using methanol for this process.

The FED has also financed studies and plans a small project to compress gas (for possible use on motor cars in the Gisenyi area) in 1982 and a urea factory in Gisenyi in 1986.

Government of Rwanda Policy

The Government of Rwanda and Zaire have formed a "Société Mixte" for the exploitation of methane gas. An agreement was reached in 1978 that 47.2% of production would belong to Rwanda, and 52.8% to Zaire.

An unresolved problem arises from the fact that matching investments are required i.e. for each factory built in Rwanda, a similar investment must be made in Zaire.

The CEPGL organization also has an interest in methane gas exploitation, insofar as it affects the economic development of the 3 member countries.

Conclusion

The vast reserves of methane gas in Lake Kivu are potentially an extremely valuable source of energy for Rwanda. Even if the gas is not renewable, and if only half of the estimated reserves can be exploited, (i.e. approximately 30,000 million m^3) there would still be sufficient energy to power 20 factories the size of the large Katana cement factory for almost 100 years. However, the Lahmeyer report states that "Up to now imported products are cheaper than products derived from methane gas, with the exception of urea, which, at the proposed scale of production, would already be cheaper than imported urea".

In view of the fact that demand for methane is weak, that costs will be high, and that there remain many unresolved economic and technical problems large-scale investments in this resource would seem premature.

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(1) SAARBERG INTERPLAN estimate of Katana Energy requirements is 16 million m^3 per day at full capacity.

PEAT

Introduction

It is estimated that peat reserves of from 5-50 million tons exist in Rwanda, of which 10% are believed to be of high quality. Up to now there has been very little development of this resource. Peat was first used in Rwanda in the 1960's, when the Gishoma marsh located in extreme south west of the country was exploited to provide peat for the Katana cement factory in Zaire. When the cement factory closed, peat extraction was terminated. Since 1974 peat from the Cyabaralika marsh in Ruhengeri has been used by OPYRWA for drying pyrethrum. Peat from Kiguhu marsh in Ruhengeri is presently used in the Belgian Project - pouzzolanes-chaux-tourbe (PPCT), which will produce cement using volcanic material. The most recent peat bog to be exploited is that of Busoro in southern Rwanda, where a pilot extraction project is being undertaken.

Formation

Peat is formed by the decomposition under water of marsh vegetation. It is found in layers, with surface vegetation - which may be floating- covering a layer of "White peat" - or semi-decomposed material, beneath which is a layer of "black-peat" fully decomposed material, valuable for its combustible properties.

In Rwanda, the marshes in which the peat is found are located in the bottom of river valleys at various altitudes and with areas of from a few hectares to several dozen square kilometers. Since these marshes are stream fed they contain impurities not found in the flat, rain-fed peat bogs of Europe, and the peat is generally of a lower quality. Furthermore their dispersed locations renders the peat less homogeneous and less accessible than European deposits. These differences have caused several problems in the exploitation of the peat.

Exploitation

In Rwanda peat is extracted manually, with drainage of the marshes in Cyabaralika and Kigulu, and without drainage in Busoro. Where drainage is necessary main and lateral drains are first excavated and peat is cut from the sides of the lateral drains and deposited beside then for partial drying. It is then transported to the drying area, dried, turned, and stocked in piles. The excavation normally takes place at the time of year when the water level is lowest. The rate of production depends on the size of the drying area and the rate of drying, which in turn depends on climatic conditions. A similar process is followed where drainage is not required or not possible. The main difference is the absence of drainage structures. In Busoro geological conditions do not permit drainage of the marsh, making exploitation extremely difficult.

The quality of peat extracted manually is inferior to that which would be obtained by a mechanized or semi-mechanized process. However, this must be weighed against the problems inherent in importing, setting up and maintaining equipment. Only where the peat is beneath several meters of water is mechanization essential.

Uses

White peat mixed with other chemicals is valuable as a fertilizer. In Rwanda some of the most fertile areas are the valley bottoms and several peat marshes have been exploited for their agricultural value rather than for their energy potential.

Black peat can be used domestically to replace charcoal or wood. The main disadvantage is that it gives off a larger amount of smoke and takes longer to ignite. It is used successfully in industrial processes such as pyrethrum-drying, brick and tile making, and was formerly used in combination with diesel to supply power to Katana cement factory.

Peat of high quality (i.e. with low ash and moisture content) may be transformed into coke, which has a higher calorific value. This product would be important primarily for industrial uses, since dried peat as such is adequate for domestic purposes.

Donor involvement

Up to now only three donors have been involved in the development of this resource: reland, Belgium and the UN (UNIDO).

Following two 1978 reports by a UNIDO consultant (J.Martin) an agreement was reached in early 1980 between the Rwandan Ministry of Natural Resources and the Irish Foreign Ministry to implement the first phase of a peat exploitation project. This consisted of investigating possible peat production areas, evaluating the quality of the peat by laboratory analysis, and implementing a pilot exploitation to test techniques and produce a preliminary 1,000 tons of dry peat.

As a result of this agreement, a survey was undertaken, starting in the environs of Kigali, particularly the Nyabarongo and Akanyaru valleys. The nearest site to Kigali suitable for exploitation was found to be Butaro marsh, on which some trials had been made by the Ministry of Natural Resources in 1979.

During 1980, only 150 tons of sod peat were obtained, due to technical difficulties in exploiting the peat. The production cost of this peat was estimated as 1,050 Frw per dry ton, on the basis of labour costs of 100 Frw per 8 hour day.

In 1981 it is planned to produce 500 tons of peat from Busoro between mid July and the end of October using a semi-automatic machine for macerating the peat. The production target for 1982 is 1,000 tons. Problems regarding the site of this project and mentioned in the Martin 1980 report do not appear to have been confronted. The first of these is that the marsh is presently cultivated during the dry season. The exploitation of peat obviously conflicts with this use of the land,

since it can no longer be cultivated. A second problem lies in the fact that continued excavation of peat in this marsh will eventually turn the area into a lake.

Belgian aid produced a report on the exploitation of peat in 1980 and is interested in contributing to the development of the resource at the preparatory stages, - identification of reserves and sampling and analysis of peat. They also intend to use the peat from Cyabaralika for the PPCT cement-making enterprises.

GOR Policy

The Ministry of Natural Resources, is responsible for the development of peat resources in Rwanda. They are presently engaged in a comprehensive survey of the country's reserves. Exploitation of the Busoro marsh is being accompanied by an education campaign on the uses of peat, as a preliminary measure to its marketing as a replacement for charcoal in Kigali and other urban areas. The main objective of Government policy is the replacement of charcoal as far as economically feasible in order to alleviate the fuel-wood crisis as much as possible.

Conclusion

There are undoubtedly large reserves of peat existing in Rwanda. However, only a small percentage of these are of high quality, and probably an even smaller percentage are economically feasible to exploit.

While peat is attractive as a substitute for charcoal, and will become increasingly so as wood supplies diminish in proportion to demand, it will be necessary to examine carefully the costs of production in Rwanda as compared to the costs of importing wood from Zaire, where abundant supplies still exist. In view of the scarcity of good agricultural land,its loss as a result of peat extraction is a major cost to be considered in evaluating the development of this resource.

NON-TRADITIONAL ENERGIES -SOLAR, BIOGAS, GEOTHERMAL AND WIND.

In order to exploit the potential of the non-traditional energy sources in Rwanda, the Government instituted in 1974, the "Centre d'Etudes et d'Applications de l'Energie au Rwanda" (CEAER) which is part of the National University of Rwanda. This institution is responsible for studying potential new small-scale energy sources and for designing and testing appropriate technologies for its exploitation. The Center is presently organized in four departments which specialize in biomass solar energy, meteorology and mini hydro-power plants.

SOLAR ENERGY

The CEAER has been carrying out research on solar energy since 1974, and has collected meteorological data including hours of sunlight, temperature etc, since 1977. Statistics are collected from 30 stations covering all the climatic zones of Rwanda. This information will provide the basis for planning the future development of this resource.

In addition to research, the Center has developed solar equipment including water-heaters, distillers, cookers and dryers. So far 27 water heaters have been installed, 2 in hotels (Guest House Gabiro and Hotel Akagera), 1 in Kigembe Hospital, 1 family unit in Kigali, 11 in the SOS Village, Kigali and 12 in the UNR houses. Two water distillers have been installed, one in Kigembe hospital and one in Gisagara health center. Cookers and dryers are being tested at the Center and initial results are positive. Refrigeration units have also been tested and 10 are to be in place by 1982.

Because of its potential widespread use, most research is now concentrated on the solar cooker. The major problems to be solved relate to the fact that it doesn't operate at night and that there is no temperature control. The former point is particularly important since most Rwandan families have their main (often only) meal in the early

evening. The problem of storing energy generated during hours of sunlight is receiving particular attention. Although storage technology exists, it is very expensive. Solar cookers are generally considered a potential supplement rather than a substitute to the traditional stoves.

Apart from the work being undertaken by the CEAER, two other projects are of interest. The first is a radio relay station on Mount Kinanira near Cyangugu for short wave transmission beyond the Zaire-Nile crest. This installation is powered by a solar generator and includes 52 m^2 of photovoltaic pannels. It was constructed in early 1981 by a German company (AEG - Telefunken).

A second small project is at Kabgayi mission near Gitarama. This project imports, sells and installs solar pannels.

Plans for the future development of solar energy are mainly concentrated on increasing the number of solar generators in rural health centers. The Government in the 1981 development budget provided 50% financing for generators in two health centers, and the FED will contribute the other 50%. The energy produced will be used mainly for lighting and refrigeration. The Government plans eventually to provide a further 100 health centers with solar energy. There is also a proposal to equip 100,000 households with solar power for lighting: a project which would be spread over 8 years.

BIOMASS

The first research and experimentation on biomass as a potential source of energy was carried out in 1977. Since then research has been undertaken on the development of algae cultures, appropriate technology for pressing papyrus into briquettes, and appropriate technology for transforming peat into coke.

Apart from research, several experiments have been undertaken with biogas digestors of different sizes. The biogas digestor is an airtight receptacle in which animal or vegetable wastes and water are transformed during a period of several weeks by bacterial action into a combustible gas of 60% - 70% methane content. The first experimental digestor was tested in late 1977 using cow manure and papyrus wastes from the Zaza paper-making project. Experiments using papyrus alone produced only half as much gas as when combined with a small amount of manure. Animal wastes alone produced the greatest amount of gas.

Three digestors are currently being used to produce gas as a substitute for wood or charcoal.

The CEAER, in collaboration with the authorities of the Ecole Technique Agricole de Butare (ETAB) designed and installed a 12 m^3 digestor which produces most of the energy for cooking meals at this school. A second digestor is used in Butare prison, also to provide energy for cooking, and a third, small ($2m^3$), installation provides gas for a house used by French volunteers.

While experiments are underway with small, household digesters, a 10-30 family collective unit seems at present to be the smallest feasible size. Gas produced by such a unit could be used domestically for cooking, and lighting, or it could be used by health centers for refrigeration.

The use of biogas as an alternative to wood could have a major impact in regions of the country where the latter is particularly scarce, such as in parts of Bugesera. But though the technology was primarily developed to provide an alternative source of energy, there are two other major benefits which derive from the gasification process. Firstly, from the point of view of hygiene, the destruction of parasites, flies, etc. during the transformation process is extremely beneficial. Secondly,

the residual after the production of gas is a high quality fertiliser which contains nitrogen, phosphates and potassium.

In combination with solar energy, biogas has the potential to satisfy limited, regional requirements, and could be of particular importance for domestic energy consumers in those areas deprived of wood, and for institutions in areas where wood and electricity are unavailable.

While considerable progress has been made in the development of this resource, efforts to encourage a wider distribution are required, and there are still some areas of research which merit more attention. To specify but one, the compression of coffee husks, presently dumped on roadsides in Rwanda, has been successfuly undertaken in Kenya,and the product commercialized as a fuel. There would seem to be considerable potential for this in Rwanda.

Financing from several donors has been obtained for the further development of this resource. Since 1979 USAID has been providing funds for CEAER activities; a German society, BORDA is supporting a project for the installation of 210 household digestors, and the FED signed an agreement in 1980 to aid experimental production of biogas.

GEOTHERMAL

Geothermal energy is generally found in regions which experience, or have in the past experienced ,volcanic activity. Several thermal springs are known to exist in Rwanda in the area of Lake Kivu, in proximity to the volcanoes, with temperatures in some cases in excess of 60 degrees C. No studies are known on this source of energy in Rwanda.

WIND

There does not seem to be much potential for the development of this source of energy in Rwanda since the wind is irregular and generally not strong. However, in Kibungo Prefecture, Makarange Parish, a small installation is in place and produces about 100 W. Wind speed here averages around 4m/sec, very little above the minimum required of 3m/sec.

Conclusions

The two major sources of energy currently supplying Rwanda's needs are hydro-electric power and wood. The former supplies a very limited market, including industries, the administrative and service sector, and a relatively small number of urban consumers. The degree of market concentration for electricity is illustrated by the number of subscribers-approximately 4,500 out of a total country population of 5 million. Although the distribution network has been considerably extended in the past 3 years, and further extensions are planned, the dispersed settlement pattern in conjunction with low rural incomes will prevent widespread domestic use of electric power for many years to come.

Forecasts of electrical energy requirements indicate that there will be an adequate margin between supply and demand if the new power stations-- Mukungwa, Ruzizi II and eventually, Rusumo, come into production as scheduled. The future supply and demand balance could, however, be upset by large-scale industrial development arising from the exploitation of methane gas in Lake Kivu. According to present Government policy, the proposed heavy industries will be obliged to fulfill their energy requirements by the use of hydro-electric power. If this policy is maintained and enforced, demand forecasts will have to be revised and a strategy developed to satisfy the increased requirements.

A far more widely used source of energy is wood, which is employed by over 90% of the population, mainly for cooking but also for heating in high altitudes. According to recent surveys supplies of wood are rapidly diminishing, despite efforts by the Government and agricultural projects to engage in reforestation. While these efforts may prevent a deterioration in the situation, it is not likely to undergo a dramatic improvement, since a growing population is requiring more and more land to cultivate food crops.

Dwindling wood supplies in Bugesera will have a particularly marked effect on the supply of charcoal, which is produced in that region. It is planned to market peat as a substitute for charcoal, which is presently used by approximately 95% of the population of Kigali, in addition to consumers in other urban areas.

As far as the two potential new energy sources are concerned, methane gas and peat, they are both at a relatively early stage of development and many uncertainties exist regarding their exploitation and use.

Three peat marshes are presently being exploited in Rwanda, all on a small scale. Two of these marshes are drainable and the technology for extracting the peat is fairly straightforward. The peat produced is used industrially for pyrethrum drying and cement production. A third marsh, Busoro, in southern Rwanda is not drainable and the Ministry of Natural Resources is presently undertaking experiments to find the most appropriate technology for extraction of the peat. The Ministry intends to establish a Peat Office to administer the commercialisation fo peat for domestic use and a consumer education program is underway to facilitate this. Peat has the advantage of providing more uniform and easily controlled heat than fossil fuels. The main disadvantages of peat as a domestic fuel are that it takes a long time to ignite and gives off a great deal of smoke. If these problems cannot be overcome it is unlikely that peat will have widespread use, although it may replace charcoal in the intermediary stage between the virtual exhaustion of the Bugesera reserves and the possible advent of methanol stoves.

The production of methanol and urea fertiliser seems to be the major potential of the methane gas deposits in Lake Kivu. While the raw gas is obviously the cheapest product, transport and storage difficulties render its use very localised. When transformed into methanol, it has several potential uses including lighting, heating, possible transformation into gasoline when the technology is further refined , and use in methanol powered vehicles.

This resource has been studied for over 40 years and the end has probably now been reached in academic research studies. The next step must be intermediate sized plants, which would serve for empirical research as well as being economically productive. The urea factory proposed by FED seems to have the potential to fill these requirements. The research, on, for instance, the ecological effects of methane gas extraction will have to be carried on over a number of years, and full-scale production of methane will only be a possibility in the long term.

While the needs of the major and more affluent energy consumers in Rwanda can generally be assured by hydro-electric power, the poor majority rest dependent on wood. The increasing scarcity of this resource, in conjunction with the impossibility of using substitutes such as peat or methanol in the near future, indicate that the time is ripe for alternative sources such as solar energy and biogas to be exploited to the maximum.

While a detailed economic analysis of all the alternative sources is not feasible given the many technical and economic uncertainties involved particularly in the production and marketing of peat and methane there is a need for comparative studies based on different sets of assumptions, which could be adjusted as new information became available. Such an analysis would provide a basis for estimating the most economically viable source of energy for a particular area, or for particular uses at a given point in time. As such, it would enable rational and economically stringent planning in the energy sector.

ANNEX 1

IMPORTED FUELS

The economic viability of developing Rwanda's internal energy resources depends partially on the availability and costs of alternative imported fuels. The rapidly increasing bill for imports, particularly gasoline, diesel and kerosene, is already placing a considerable burden on the meager national budget, and the situation threatens to deteriorate.

In absolute terms, the costs of imports of these fuels has risen almost 300% in the past five years (1) ($ 10 million in 1976 to $ 28 million in 1980). The bill for gasoline and diesel imports alone has risen by 2,500% over the past ten years. ($ 1 million in 1970, to $ 25 million in 1980 (2).

Of even more significance than the absolute increase in the cost of fuel imports is the relative increase vis à vis export earnings. For instance, in 1976, 12.0% of export earnings went to purchase imported fuels, while in 1980 the corresponding figure was 37.5% (3).
This not inconsiderable drain on the country's foreign exchange reserves makes it imperative to examine the possibility of substituting alternative local sources of energy.

The only potential substitute for gasoline and diesel, both of which are primarily used for vehicles, appears to be methanol. With the present state of technology, methanol can be used as an additive to traditional fuels, replacing 10-15% of the mixture. Of more interest is the possibility of transforming gasoline - consuming vehicles to run on methanol, or the introduction of government policies to encourage the importation of vehicles using methanol rather than these powered by gasoline.

As regards kerosene, which is used mainly in lamps, two potential substitutes are hydro-electric power and solar energy. The former would probably be more feasible in the vicinity of urban areas, the latter is possible for more isolated districts.

(1) See Table 1

(2) Ministry of Finance statistics

(3) See Table II

The cost of storing solar energy is the major constraint on its use as a substitute for products used for lighting. A fairly accurate cost comparison of hydro-power, solar energy, and kerosene can be made with information currently available, to determine the most economic option for any given area.

Thus, locally produced substitutes for imported fuels are available, though at present they may not be economically viable. However, the dramatic increase in the costs of imports, both in overall terms and as a percentage of export earnings, indicates the advisability of developing strategies for the exploitation of local energy sources to ensure that future energy requirements may be met in the most economically efficient manner.

TABLE I

Imported Fuels 1977 - 1980

(weight : tons)
(value : 1,000 RWF)

Product	Gasoline (1)		Diesel		Kerosene	
YEAR	Weight	Value	Weight	Value	Weight	Value
1976	15,097	487,638	14,783	360,794	4,191	100,555
1977	17,601	561,672	12,014	305,232	2,970	81,055
1978	20,571 (2)	716,519	12,377	356,202	4,963	137,803
1979	18,591	921,004	13,529	514,765	6,203	269,880
1980	23,326	1,512,225	14,285	757,866	5,438	265,512

Sources : 1976 - 1978 Gasoline and Diesel imports : Ministry of Finance
1977 - 1978 Kerosene imports : Ministry of Plan, Statistics Bulletin No. 60
1979 & 1980 all figures from Ministry of Finance.

(1) Not including aviation fuel
(2) deliveries disrupted by Uganda war

TABLE II

Imports of Gasoline, Diesel and Kerosene as a percentage of all imports and of all exports

YEAR	TOTAL IMP. (1)	TOTAL EXP. (1)	GASOLINE % of all IMP.	GASOLINE % of all EXP.	DIESEL % of all IMP.	DIESEL % of all EXP.
1976	9,315	7,473	4.7	5.9	3.9	4.8
1977	10,579	9,983	5.3	5.6	2.9	3.0
1978	16,628	8,094	4.3	7.1	2.1	4.4
1979	18,055	11,146	5.1	8.3	2.9	4.5
1980	22,051	6,766	6.9	22.4	3.4	11.2

	KEROSENE % of all IMP.	KEROSENE % of all EXP.	TOTAL FUELS % of all IMP.	TOTAL FUELS % of all EXP.
1976	1.1	1.4	9.7	12.0
1977	.7	.8	8.9	9.4
1978	.8	1.7	7.2	13.2
1979	1.5	2.4	9.5	15.3
1980	1.2	3.9	11.5	37.5

Sources: 1976 - 1978 statistics Ministry of Plan
1979 & 1980 statistics Ministry of Finance

(1) in 1,000,000 RWF

ANNEX II

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BIROLI P.	Ministry of Agriculture
DREHER A.	ELECTROGAZ
FEUILLY	Swiss Aid
KARERA E.	Ministry of Natural Resources
LANGOUCH M.	UNDP
LUFT M.	LAHMEYER INTERNATIONAL
NKUBANA A.	Ministry of Natural Resources
NSENGIYUMVA I.	BUNEP
PATTERSON R.	UNDP
SHEFFIELD R.	F.E.D.
SHWARTZ J.	Ministry of Planning
STRATTON M.	ELECTROGGAZ

A new initiative at the commune level involves giving usufructary rights to unoccupied land to an individual or group of individuals to plant trees. The bourgmaster is responsible for this activity, which has already been started by some individuals. Where land use rights are given to a group, each has an individual plot, and all plots must be planted the same year.

On a more general level the Ministry of Agriculture is encouraging the development of agro-forestry projects, and the integration of a forestry element into agricultural projects. Additionally it is planned to increase the surfaces planted to trees, where land is still available, particularly on the Zaire - Nile crest.

Contribution of Aid Agencies

Many of the organised forestry activities are being undertaken by foreign aid projects. The first such project was the Swiss-financed Pilot Forestry project in Kibuye. Started in 1967, this project incorporated training, research, extension work and reforestation in Kibuye prefecture and on the borders of the Nyungwe forest. By early 1980, 2,250 hectares had been reforested.

The FAO Agricultural Intensification Project in Gikongoro aims to replant 750 hectares per annum; 1268 were planted between 1977-1979.

A large reforestation program was implemented by the Nyabisindu agro-pastoral project, financed by Germany. Between 1975 and 1978 a total of 4,200 hectares were planted, of which 145 were fruit trees.

Finally, the BGM project in Bugesera planted approximately 870 hectares between 1977-1979.

Future projects include : reforestation of the Gishwati forest with 5,000 hectares of pine, and 5,000 hectares of eucalyptus, financed by the World Bank : reforestation of 5,000 hectares in Kigali prefecture and 3,000 hectares in Butare, also financed by the World Bank : reforestation of 1,000 hectares, bordering on Nyungwe, financed by Belgium : and projects on the Zaire-Nile crest financed by F

In addition to these projects financed by international donors, private enterprises such as tea factories are undertaking small scale projects to supply their own energy needs in processes such as tea drying.

Conclusions

A basic element in the fuelwood shortage is the existence of conflicting demands for the use of scarce land as the population increases.
At the farm level, the first priority is planting a sufficient area of food crops to feed the family. Fuel is of secondary importance, and dried banana leaves and other residues are used when wood is not available. This attitude is understandable, in a society where family food self-sufficiency has a long tradition.

Whether or not, and if so under what conditions, planting trees could be more profitable for a farmer than planting food crops is a question which remains to be studied. In the short term, however, national, prefectural and communal authorities must take responsibility for assuring adequate wood supplies.

In the longer term the following factors will contribute to the amelioration of the problem:

1) Reforestation efforts. In the past 5-6 years, approximately 10,000 hectares were reforested by the projects mentioned above, and reforestation of a further 20,000 hectares is planned. This is in addition to commune and private reforestation projects.

2) It is planned to replace charcoal by peat from the Busoro marsh. An education campaign on the use of peat is already underway.

3) The extension of the electricity distribution network, in combination with rural-urban migration, will increase the use of this resource.

4) Several alternative sources of energy for use in rural areas are being studied. These include solar, biomass, methane products, wind and mini-hydro-power schemes.

These activities, as part of a national energy program should contribute significantly to an improvement in the fuelwood situation.