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Institutional requirements and technical alternatives for a small hydropower program

NRECA Small Decentralized Hydropower (SDH) Program

BURUNDI: Institutional requirements and technical alternatives for a small-hydro program

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Preface and acknowledgments

In April 1982, REDSO/EA conducted a preliminary assessment of Burundi's small-hydropower program at the request of the USAID Mission in Burundi. In turn, this preliminary assessment was in response to a request from the Government of the Republic of Burundi for U.S. technical assistance in strengthening the small-hydropower program. Government activities in rural electrification by means of decentralized hydro development began in Burundi in the late 1970s.

The first step taken as a result of the preliminary assessment of April 1982 was a one-month assessment of Burundi's small-hydropower program by a two-man team from the National Rural Electric Cooperative Association (NRECA) under a cooperative agreement with USAID (AID/DSAN-CA-0226). The present report is the result of that assessment. In accordance with the terms of reference, the report emphasizes training and manpower needs for institutional strengthening, options for financing small-hydro development, and ways to improve technical planning. Actual hydropower sites were assessed in the field to the extent that it was possible during a one-month visit.

Team members were Mr. Allen R. Inversin (Micro-Hydro Engineer) and Dr. Robert C. Zimmermann (Resource Management/Energy Planning, on leave from Associates in Rural Development, Inc.). They were in Burundi from October 27 until November 19, 1982. The team was able to visit selected field sites within the area encompassed approximately by Buhiga in the north, Ruyigi in the east, and Rumonge in the south.

The team is indebted to Mr. George T. Bliss (AID Affairs Officer), Ms. Abbe Fessenden (Program Officer), Mr. Michael Sullivan (Assistant General Dev. Officer), Mr. Ronald Ruybal (IDI-Agriculture), Mr. Samson Ntunguka (Administrative Assistant), and Mr. Guy Gibson (Administrative Officer), all of USAID/Burundi, for guidance, encouragement, and practical assistance.

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Among the expatriate advisors, special thanks are due to M. Robert Gambart, Ing. (Belgian Technical Cooperation), and M. Bernard Crétinon, Ing. (French Cooperation), who bore the brunt of many technical questions and provided guidance in the field. The help of M. Philippe Zozzi, Ing. (Swiss Consul and MTPEM/ORT), M. Pierre Rucquoy, Ing. (UN/IDA), M. Renato Panfietti (FED), and the hospitality of the religious missions at Kibimba, Ruyigi, Butezi, Musongati, Buhiga, Giheta, and Zamandore and of M. and Mme. Hubert and Leone Verhulst of Murago are gratefully acknowledged.

DGE	Direction Générale de l'Energie (MTPEM)
DHER	Département de l'Hydraulique et de l'Electrification Rurales (MDR)
FAC	Fonds d'Aide et de Coopération (France)
FED/EDF	Fonds Européen de Développement/European Development Fund
GRB	Government of the Repubic of Burundi
GTZ	Gesellschaft fuer Technische Zusammenarbeit (W. German technical cooperation)
KfW	Kreditanstalt fuer Wiederaufbau (W. German Credit Institute for Reconstruction)
MDR	Ministère du Développement Rural
MTPEM	Ministère des Travaux Publics, de l'Energie et des Mines
NGO	non-governmental organization
OJT	on-the-job training
REGIDESO	Régie de Production et Distribution d'Eau et d'Electricité
SDH	small decentralized hydro (in the context of Burundi, plants of up to 250 kW capacity, not connected to REGIDESO's grids)
UNDP	United Nations Development Program

Background summary

The small central African nation of Burundi is mostly hilly to mountainous, with rainfall ranging from 800 to 2,000 mm per year. The drainage network consists mainly of small to medium-sized perennial rivers. As a result, the country has an excellent potential for the development of hydroelectric plants. With a maximum electrical power use at present of 10-20 MW, which provides an electrical energy totalling 60 GWh, hydropower plants can make a significant impact in reducing fuel imports. Perhaps of greater significance is that, given the scattered nature of the resource, small decentralized hydropower plants can also readily provide energy for the development of the rural areas which will not be within reach of the national grid for years to come. Existing Mission small-hydropower plants, plants with capacities less than about 250 kW, have an installed capacity of about 400 kW while those presently being implemented by DHER have a total capacity of about 700 kW.

Small-hydroelectric development in Burundi was initiated by religious missions in the 1930's. The number of small plants grew slowly to at least 12 by the late 1970's. These plants were almost wholly designed, financed, built, operated, and maintained by missionaries. They usually served the missions themselves and ancillary facilities such as schools, dispensaries, or hospitals.

By the late 1970's, the focus of small-hydropower activities shifted to the Government of Burundi. This shift occurred under the impetus of increasing prices of imported oil after 1973-74 and of a new program of rural development that included more efficient delivery of basic services (water, power, health care, and education) and promotion of agricultural productivity and small rural industry. The program included the creation of new rural centers, the so-called villagisation program. Rural electrification was to be made possible by, and to serve as an incentive for, villagisation.

As the villagisation program implies, most of Burundi's four million rural residents live in dispersed farm settlements. Relatively isolated individual rural households are indeed the norm in most of rural Burundi. The implication of this settlement pattern to small-hydro development is that, whereas hydro potential is usually available, the loads (households, farms, small food processing, etc.) to justify the construction of plants and of transmission lines often are not.

Recognizing the special needs of rural development, the Government of Burundi in 1970-80 established an agency responsible for decentralized rural electrification, the Département de l'Hydraulique et de l'Electrification Rurales (DHER). Until then, REGIDESO, the parastatal water and power authority, had the exclusive mandate to distribute water and power. REGIDESO is still involved in "small" hydropower, as it is responsible for all installations of over 250 kW capacity and has an interest in plants below this capacity. The lack of clear demarcation of responsibilities between DHER and REGIDESO is one of the institutional problems that affects small-hydropower development in Burundi.

In 1980, the Government also established a Direction Générale de l'Energie (DGE) which was to serve as the central energy planning and coordinating unit of the government. This agency is mandated to provide national energy planning, and thus overall guidance to small-hydropower development. This new agency is,

however, badly understaffed and so far has neither been able to provide this guidance nor to resolve jurisdictional disputes.

As of November 1982, there were at least 22 small-hydropower plants and another six plants with capacities ranging from 280-8,000 kW in operation or under construction in Burundi. DHER has another five plants scheduled, with capacities from about 40-200 kW. In 1978-82, DHER and NGO's invested about FBu 175 million (US$ 1.9 million) in small-hydro development including low-voltage grids. The State contributed about one-third of this amount. The total proposed for 1983-87, including logistical support, is about FBu 650 million (US$ 7.2 million). It is foreseen that most of these funds will come from external sources.

Until now, the small-hydro program has been entirely devoted to systems design and construction of plants for the larger existing rural centers, including missions and related facilities. The program has been unduly preoccupied with construction problems and delays due to shortages of skilled manpower, funds, transport, equipment, and materials. Extensive rural electrification is probably many years or decades away, not only because of the problems mentioned, but because of dispersed farmsteads, unsuitable traditional housing, scarcity of rural industries and business, extremely low purchasing power, unfamiliarity with electricity, and a reported widespread lack of interest in electrification. However, in order to sustain the modest program now underway, the existing institutional framework should be strengthened and the foundations laid for an eventual acceleration of rural electrification.

On the technical side, the designs of many of the existing plants, both mission plants as well as those being implemented by DHER, have been the work of a single self-taught priest working with one of the missions in Burundi. His expertise has also been relied upon during the construction of many of these schemes. However, this and other indigenous experience has not been fully capitalized upon and lessons learned from past problems and design options developed in other nations have not been methodically incorporated in new designs more suitable for Burundi, designs which would reduce costs and complexity of small-hydropower schemes. In addition, this expertise has not been institutionalized so that it is available to private as well as to governmental developers of sites as needed.

Recommendations

1. The Government of Burundi should pursue its small-hydropower program as an effective means of supplying a renewable form of energy to small rural centers.

2. DHER should establish a standard design philosophy with a view toward reducing cost, simplifying construction of their schemes, and minimizing maintenance requirements which will be encountered during the plants' operation.

3. In order to extend rural electrification to individual, or to small collective, users, DGE and DHER should consider developing the country's micro-hydro potential (less than about 50 kW) by utilizing simple designs already in use in other developing countries, local manufacture of turbines, and designs for overall plants and implementation strategies which are more appropriate to the realities of Burundi's rural areas.

4. DGE, in collaboration with DHER, should survey existing and potential uses of energy in the rural areas so that excess hydropower of small plants can be directed towards these uses, thereby generating employment in rural areas and increasing the financial viability of the small-hydropower program.

5. The mandates of REGIDESO and DHER should be formally defined on the basis of respective limits of installed capacity and of declared urban and rural zones so as to avoid overlapping jurisdictions. The roles of REGIDESO and DHER should eventually be spelled out clearly in a national energy plan.

6. DGE should be assisted in its efforts to provide coherent national energy planning, including the role of small hydro in relation to other energy alternatives. The request for at least two national energy planners should be supported.

7. DHER should strengthen its capacity to evaluate and plan the technical and economic aspects of small-hydropower development.

8. DHER should be given the manpower and other resources to enable it to provide adequate overhaul maintenance and other technical assistance to all operators of small-hydro plants.

9. DHER's plans to provide maintenance and construction support through three Bureaux Régionaux (Régional Offices) should be supported.

10. DHER's small-hydropower program should be placed increasingly on a self-supporting basis. DHER should charge institutional users for power delivered.

11. Gradual introduction of flat and metered rates for individual users should occur once a sufficient number of these users are connected.

12. Other recommended means of generating revenue for small-hydropower development are sales of surplus power and plants to REGIDESO, transfer

payments or grants from REGIDESO, sale of plants to rural electric cooperatives, and sales of goods and services produced with surplus energy from small-hydro plants.

13. As rural electrification by means of small hydropower proceeds, the various technical, management, and operational functions should be divided among central (DHER), regional (Bureaux Régionaux of DHER), and local (missions, communes, cooperatives) structures; the principle of maximum delegation of functions consistent with efficient performance and use of manpower and other resources should be followed.

14. A training program, both in-country and abroad, has been recommended for each new professional/technical position proposed. The total estimated cost of this training is US$ 127,000-220,000 spread over eight or more years. The total cost of training of personnel needed within the next 2 years is in the US$ 98,000-160,000 range.

Recommendations (French translation)

1. Il est recommandé que le gouvernement du Burundi poursuive son programme de développement hydroélectrique à petite échelle car ce programme est un moyen efficace de fournir une forme d'énergie renouvelable aux petits centres ruraux.

2. Il est recommandé que le DHER établisse des normes de conception des centrales afin de réduire les coûts, de simplifier la construction et de minimiser les besoins d'entretien une fois que les centrales entrent en fonction.

3. Afin de réaliser une électrification rurale à la portée des petits usagers collectifs ou individuels, il est recommandé que la DGE et le DHER étudient le concept du développement du potentiel micro-hydroélectrique (moins de 50 kW) par le moyen de conceptions simples déjà utilisées dans des autres pays en voie de développement, de la fabrication locale des turbines et par des conceptions générales des centrales et stratégies d'exécution qui sont mieux adaptées aux réalités des milieux ruraux du Burundi.

4. Il est recommandé que la DGE dresse, en collaboration avec le DHER, un inventaire des utilisations actuelles et potentielles de l'énergie en milieu rural afin que l'excédent de la génération des petites centrales soit dirigé vers ces utilisations et afin de créer des emplois dans les campagnes et d'améliorer la situation financiere du programme hydroélectrique à petite échelle.

5. Il est recommandé que les mandats de la REGIDESO et du DHER soient définis formellement en fonction de limites respectives de la capacité installée et d'une déclaration de zones urbaines et rurales afin d'éviter le chevauchement des juridictions. L'attribution définitive des mandats à la REGIDESO et au DHER devrait être bien précisée par un plan énergétique national.

6. Il est recommandé que la DGE soit appuyée dans ses efforts d'élaboration d'un plan énergétique national cohérent dans lequel le rôle du développement micro-hydroélectrique est défini face aux alternatives énergétiques. La demande d'engager au moins deux préposés à la planification est à soutenir.

7. Il est recommandé que le DHER renforce sa capacité d'évaluation et de planification des aspects techniques et économiques du développement hydroélectrique à petite échelle.

8. Il est recommandé que la main-d'oeuvre et les autres ressources nécessaires soient mises à la disposition du DHER afin que cette agence puisse fournir des services compétents d'entretien.

9. Il est recommandé que le projet du DHER de fournir des services d'entretien et d'assistance à la construction par l'entremise de trois Bureaux Régionaux soit appuyé.

10. Il est recommandé que le programme micro-hydroélectrique du DHER soit mis sur une base d'auto-financement croissant. Le DHER devrait débiter les frais de fourniture de l'électricité aux clients institutionnels.

11. Il est recommandé que des tarifs forfaitaires et au compteur pour clients individuels soient introduits une fois qu'un nombre suffisant de ces usagers sont raccordés aux réseaux du DHER.

12. Les autres moyens recommandés pour créer des fonds de développement micro-hydroélectrique comprennent la vente d'électricité et de centrales excédentaires à la REGIDESO, le transfert de paiements ou de contributions de la part de la REGIDESO, la vente de centrales aux co-opératives d'électrification rurale, et la vente de produits ou services fabriqués ou fournis avec l'énergie excédentaire des petites centrales.

13. Au fur et à mesure que l'électrification rurale par micro-centrales se développe, les diverses fonctions techniques, de gestion et d'opération devraient être partagées entre les structures centrales (le DHER), régionales (Bureaux Régionaux du DHER), et locales (Missions; Communes; Co-opératives); pour effectuer cette division des fonctions, il est recommandé de suivre le principe de délégation maximale des fonctions, compte tenu de l'exécution efficace du travail et de l'utilisation rationnelle de la main-d'oeuvre et d'autres ressources.

14. Un programme de formation, au Burundi et à l'étranger a été recommandé pour chaque nouvelle fonction professionnelle ou technique proposée. Le coût total estimé de ce programme de formation est de US$ 127,000-220,000, étalé sur une période de huit ans ou plus. Le coût total de la formation du personnel exigé pour les deux années à venir est de l'ordre de US$ 98,000-160,000.

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INTRODUCTION

Like most developing countries, Burundi faces several interrelated energy, environmental and other socio-economic problems. A major problem is deforestation and a dwindling supply of fuelwood, the main source of energy for the overwhelming majority of the population. Substitute forms of energy, particularly petroleum fuels, are not easily available. Indeed, the ever-increasing costs of imported fossil fuels and precarious supply lines are forcing Burundi to seek ways to control or even diminish fuel imports through substitution with domestic energy sources. Other problems include the heavy reliance on imported hydroelectricity and the acute need to make available to a large rural population affordable forms of energy in order to raise living standards and farm productivity. The problem of rural energy is compounded by the highly dispersed pattern of rural settlement and by extremely low purchasing power in the countryside.

In the light of these problems and of the mountainous, well-watered nature of much of Burundi, a program of decentralized small-hydropower development is ideally suited to the circumstances of the country provided adequate power loads are found. Religious missions recognized this potential, and began developing small-hydro plants to supply their own needs as early as the 1930's. In the late 1970's, the Government of Burundi initiated its own small-hydropower program as a result of a number of developments. One was the pressure to find domestic sources of energy in view of the cost of oil imports after 1973-74. Another was the inauguration of a program of rural development which includes the consolidation of rural households in new villages for the improved delivery of basic services (water, health, education and electricity). Rural electrification was also intended to promote agricultural productivity and rural industry.

Even with clustering of settlements it is apparent, however, that rural electrification (and water supply) will remain decentralized, as extension of the few existing grids or distribution networks is largely uneconomic. Accordingly, the government has created a special department within the Ministry of Rural Development responsible for rural water supply and electrification. This department is thus separate from the main national water and power authority, in recognition of the special needs of rural development.

Like all new programs, Burundi's small-hydropower program suffers from a number of administrative and technical problems. The main and immediate ones are inadequate manpower, financial, equipment and other resources. However, weaknesses in the institutional framework and in the general orientation of the program, particularly the balance between construction and load development, also need attention to ensure the long-term soundness of the program. It is the purpose of this report to assess Burundi's small-hydropower program, to identify its strengths and weaknesses, and to propose remedies where these seem needed.

HYDROPOWER RESOURCES AND ELECTRICITY CONSUMPTION

Most of Burundi has physical conditions which encourage development of its hydropower resources. The country is drained by a dense network of smaller rivers and streams, most of which originate on the high and humid Nile-Zaire divide. This range of mountains in the western half of the country drops westward from over 2,000 meters to Lake Tanganyika at an elevation of 800 meters over a distance of 30 kilometers. East of the divide, the drop over a total distance of about 100 kilometers is more gradual, first reaching a large central plateau and then dropping down to 1,200 meters at its eastern border with Tanzania. The range receives 1,400-2,000 mm of rainfall per year, with a dry season lasting only four months, resulting in good streamflows nearly year-round. Only in the lower, less mountainous areas, on the Rusizi plains in the northwest and in the northeastern portion of the country, the rainfall drops to 800-1,300 mm per year with a dry season that varies from five to eight months. Low flows there are correspondingly more pronounced.

The hydroelectric potential of Burundi has been the subject of several studies by foreign organizations. Most of these studies concern a particular region of the country or certain centers of special interest or activity, with a view toward locating specific sites for hydropower installations. Thus in 1978-1979, Siemens (West Germany) prepared a survey of potential hydroelectric sites in northwestern Burundi, primarily to meet the needs of the capital, Bujumbura. The survey found an exploitable potential totaling 200 MW at an annual capacity of 1,300 GWh from 29 hydropower plants ranging in size from 1.7-26 MW on either Zaire or Nile river systems. In 1981, the German Agency for Technical Cooperation (GTZ) prepared feasibility studies of eight sites ranging from 200-2,400 kW to serve larger rural centers, while in 1982 the UNDP and a French mission evaluated three sites each. At present, Lahmeyer International (West Germany) is surveying the hydropower potential of all of Burundi except the southern part, which is being evaluated by Coyne et Belier (France); both surveys are due to be completed in 1983. Although these studies have tended to emphasize hydropower sites in the middle range of capacity, it is clear that small-hydro potential is found throughout the country.

There is, however, no known survey of the small (less than 200 kW) hydropower potential of the country. This is the potential that might be exploited to serve religious missions, cooperatives, cottage industries, and government offices, as opposed to large rural centers. A partial indication of this small-hydropower potential was provided by a survey of existing microhydro plants, generally installed to serve missions and related facilities. An incomplete survey of such sites (see Annex D) found 14, located mainly in the central third of the country, stretching from Bujumbura eastward to the Tanzanian border. Though the gross head ranges up to several hundred meters for several of these plants, most operate under heads of 5-30 meters. All of the small-hydropower plants visited were within five kilometers of the load center. Since the sites of the missions which formed the nuclei for each of these centers were selected on criteria other than proximity to water and potential hydropower, usually a vantage point over valleys and hills below, it seems reasonable to assume that a large number of points within the country could be served by a small-hydro plant located within a similiar five-kilometer radius of each point. In other words, the ability of many missions to find retroactively small-hydropower sites within a reasonable distance underscores the excellent small-hydropower potential of most of the country.

In addition to the 14 known mission sites, there are now eight small sites, with capacities ranging up to 220 kW, being built by DHER. The first, at Ruyigi (70 kW), is expected to go on line in December 1982. Burundi (i.e., REGIDESO) currently has three larger hydropower plants operational: Mugere (8,000 kW), Mugera (presently at 800 kW), and Gikonge (800 kW). The plants at Mugera and Gikonge are providing power to the rural centers of Gitega and Muramvya ,

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respectively. Both plants are generating at part capacity since local loads are not yet fully developed and these plants are not interconnected with the main grid serving Bujumbura. REGIDESO has another two sites under construction: Muyinga (800 kW) and Kirundo (240 kW). In November 1982, financing was secured for the Rwegura (18,000 kW) plant on the Kitenge River in northern Burundi; the project was scheduled to be built between early 1983 and mid-1986. This plant is to serve northwestern Burundi and Bujumbura.

The map in Fig. 1 indicates the distribution of hydropower plants either under construction or operational. The map also indicates some of the proposed sites. Further details on these sites are given in Annexes D, E, and F.

At present, only two percent of the country's population has access to electricity, with the capital, Bujumbura, accounting for about 75% of this consumption, and the remaining portion consumed in the larger rural centers and tea factories (Kuntz, 1979). The total electrical energy consumption at present is on the order of 60 GWh/year, with a maximum power requirement on the order of 10-20 MW.

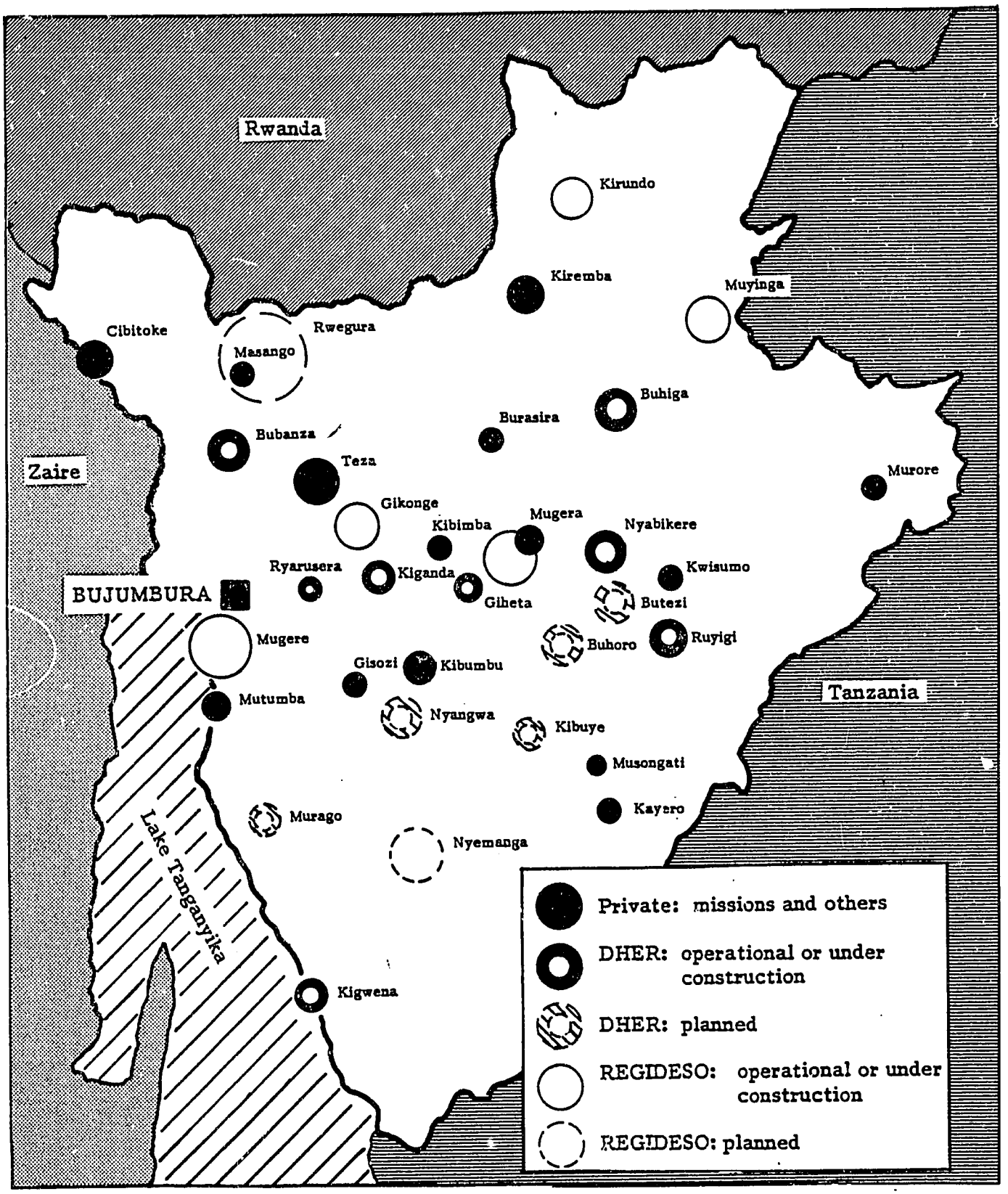

Fig. 3. Map of Burundi showing existing and some planned hydropower installations.

INTRODUCTION

Small-scale hydroelectric power was introduced to Burundi by religious missions, apparently beginning with the mission at Gitega in the 1930's. These non-governmental organizations (NGO's) have until recently financed, designed, built, operated and maintained their small-hydroelectric plants without direct government assistance and supervision. However, beginning in the late 1970's, the focus of small-hydropower activity shifted mainly to one government agency, the Département de l'Hydraulique et de l'Electrification Rurales (DHER) of the Ministry of Rural Development. This shift coincided with the new emphasis on rural development decided by the Second Republic after November 1976. Rural electrification under the aegis of DHER actually began in the course of the Third Five-Year Plan (1978-82), although it was not a systematic part of this Plan. Rural electrification by means of small decentralized hydro (SDH) was also to be part of a new policy of "villagisation" designed to regroup the highly dispersed Burundi rural households in villages where health-care, water and other government services could be delivered. Electricity was to be one way for the government to demonstrate the advantages of village life. At the same time, the government also wished to exercise some control over the missions' hydropower generation, primarily so as to extend electrification beyond the missions and their immediate facilities.

The villagisation program, which includes land re-distribution as well, has apparently begun in northern Burundi, in the Rusizi region, and elsewhere. Given the individualistic nature of Burundi's rural society, the results of this program are difficult to predict. Regardless, they affect the SDH program as they will determine future rural power loads or lack thereof. Power loads will also be determined in part by the success of the policy to promote higher crop yields, food processing, artisanal and other industry as part of overall rural development.

Shortly after the DHER was created in 1979, the GRB also established a Direction Générale de l'Energie (DGE) within the Ministry of Public Works, Energy and Mines (MTPEM). DGE was to be the central energy planning, coordinating and research unit of the government. It supervises the work of DHER, notably by reviewing plans for SDH from the standpoint of the national energy interest. DGE also affects small hydropower as it is its task to elaborate a national energy policy, in which SDH is assigned a certain role. DHER is thus essentially the executing agency. In practice, this has not happened yet, as small-hydro planning until now has been done by DHER and by REGIDESO.

REGIDESO, the parastatal water and power authority, plays a role in small hydro as it builds all plants of over 250 kW capacity. Owing to poor definition of competences (jurisdiction), REGIDESO has on occasion intervened in small-hydro projects of less than 250 kW capacity. As noted above, some small-hydro planning has been carried out on behalf of REGIDESO.

The Ministries of Planning and Finance affect small hydro indirectly as they have final responsibility for allocating investment funds under the Five-Year (development) Plans. The institutional framework that is concerned with small hydropower at the national level is summarized in Fig. 2. Aside from the missions, which still manage their own plants, there are now (late 1982) no institutions below the national level that are systematically involved in small-hydro activities. The three Bureaux Régionaux (Regional Offices) of DHER shown in Fig. 2 are not yet functional.

It should be added that the Ministry of Commerce and Industry may also have an indirect role to play in small-hydro development. This is because this ministry is mandated to promote commerce and industry throughout the country. Businesses and industries not necessarily associated directly with rural development could be potential

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customers for power from small-hydro plants. The Ministry of Commerce and Industry also sets tariffs charged for utilities, although major changes (e.g., the 70% increase in electricity rates decreed in 1980) are by Cabinet.

Hydrometeorological data of relevance to small-hydro development are collected by the Service Météorologique National. Since peat is another source of energy, ONATOUR, a parastatal authority involved in peat research and development (Fig. 2), is another energy agency that is expected to have a role in rural development.

The mandates, resources and functions of the energy agencies most directly concerned with small hydropower are reviewed in the sections which follow.

DEPARTEMENT DE L'HYDRAULIQUE ET DE L'ELECTRIFICATION RURALES (DHER)

Mandate

DHER was established and its mandate was defined by a Presidential Decree dated February 2, 1979. This decree is reproduced in part in Annex A. DHER has had its own director only since April 1980.

As Annex A shows, the small-hydropower mandate of DHER is simply to provide rural electrification. However, DHER has the following policy objectives insofar as rural electrification is concerned:

- provision of low-cost electricity ("least sophisticated system") for improving rural life and stimulating artisanal and other enterprises (mainly food processing);
- replacement of diesel generators used by local centers (secondary school, parishes, hospitals, etc.);
- promotion of the use of new or renewable domestic energy sources to avoid foreign-currency purchases of oil.

The main difficulty with the present mandate of DHER concerns the division of responsibilities between it and REGIDESO (cf. pp. 13-14). The problem of overlapping jurisdictions of these two agencies has already been emphasized in several internal DHER documents. For example, whereas in terms of installed capacity, the upper limit of DHER's responsibility is set at 250 kW, the lower limit for REGIDESO is not defined. Thus, REGIDESO is apparently interested in securing control of any hydro plant likely to be profitable. It is reported that REGIDESO is seeking control of the 70 kW Ruyigi plant now being completed by DHER. This plant will have several institutional customers (mission and bishopric, secondary school, military camp, etc.). This move by REGIDESO is alleged to be resisted at the provincial level as it would mean losing "free" MDR power.

In general, there is no geographic division of tasks between DHER and REGIDESO. There is apparently no definition of "urban" and "rural" areas where one or the other agency has jurisdiction. Adding the time dimension, there is no definition of when a developing rural center ceases to be such and thus no longer qualifies for rural-development policies. An internal DHER document (1980-81) notes, for example, that certain of REGIDESO's activities concern localities where DHER has already installed, and is maintaining, water-supply units (Bubanza, Cankuzo, Cibitoke, Karusi, Mabanda, Makamba, Matana, Rugombo, and Ruhwa). The same document urged the government to "demarcate" clearly the respective spheres of competence of the two agencies. The document suggested that the demarcation be done geographically, by designating the centers assigned to one or the other agency. The mandate of REGIDESO was reported in this document to extend to the entire country, including small rural centers of the interior. Although not strictly a problem of mandate, relations between DHER (other agencies of the government as well) and REGIDESO are strained occasionally by the loss of skilled personnel to the better-paying independent utility. The matter needs to be addressed as it undermines the small-hydropower mandate of DHER (cf. p. 24).

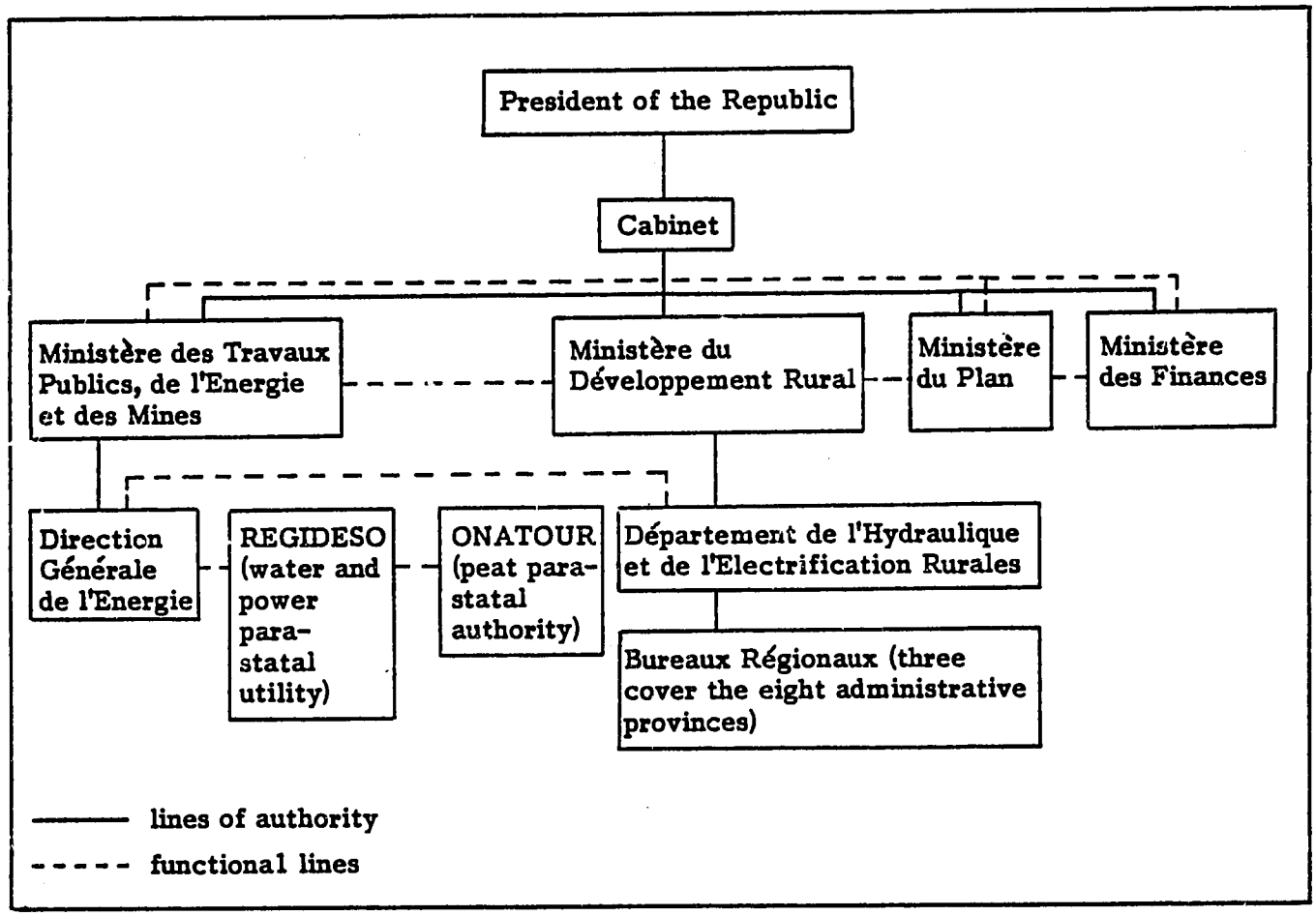

Fig. 2. National institutional framework of relevance to small-hydropower development.

Manpower

On November 1, 1982, the personnel roster of DHER (thus including the water sector but excluding secretarial staff) was the following:

1 Director (Hydraulic Engineer)
1 Deputy Director (Hydrologist)
2 Electrical Engineers (junior)
1 Administrator
1 Credit Manager
1 Accountant
1 Supervisor of Water-Supply Construction Sites
7 Water Resources Technicians
2 Electricians
2 Surveyors/Topographers
2 Draftsmen
8 Water-Supply Construction Foremen
3 Inspectors of Water-Supply Construction Sites
11 Garage Employees
61 Skilled and unskilled miscellaneous technicians (masons, carpenters, pumping-station operators, etc.)

Total professional staff concerned with small-hydro was two junior recent engineering graduates who assumed their duties on November 2, 1982. Both were trained abroad (Belgium, USSR). So far, the engineering work of DHER (apart from design work contracted out) has been carried out by one Belgian Civil (Electromechanical) Engineer provided under a five-year (1981-86) Belgian Ministry of Cooperation assistance program. Belgium also provides another civil engineer for the water-supply sector of DHER. France has made available (1981-83) a second Civil Engineer (Electro-Mechanical Systems) under the

14-month "co-operant" scheme (alternative to military service; hence, a junior engineer). FED/EDF has one expatriate civil engineer attached to DHER to supervise FED-sponsored "micro-projects" but his direct role in small-hydro has been minimal.

In preparation for the Fourth Five-Year Plan (1983-87), the Sous-Commission de Planification of MDR has submitted, on the advice of the Rural Electrification sector of DHER, the hydropower staff requirements (exclusive of expatriates) as presented in Table 1.
The figures indicate cumulative totals for each year, not additions. These requirements are termed "modest" by DHER in the light of present and projected activities (cf. Functions and problems below). Recall that, until at least 1986, one experienced Belgian engineer (electro-mechanical) is available to strengthen the professional staff.

In late 1982, DHER had no personnel below the national level. DHER is proposing to create three Bureaux Régionaux during the 1983-87 planning period. These Bureaux Régionaux will serve all eight provinces[1] and thus theoretically 78 communes (excluding the capital, Bujumbura):

- first Bureau Régional (at Gitega: provinces of Gitega, Muramvya, and Ruyigi);
- second Bureau Régional (at Bujumbura: provinces of Bururi, Bujumbura, and Bubanza); and,
- third Bureau Régional (at Ngozi: provinces of Ngozi and Muyinga).

Specific functions and manpower requirements for these Bureaux Régionaux have not yet been defined by DHER. They are foreseen primarily as maintenance centers. Suggestions concerning the staffing and functions of these Bureaux Régionaux are included in pp. 17-21 of the report.

[1] The document on which this description is based was evidently prepared before May 1982, as there are now fifteen provinces in Burundi.

Functions and problems

As noted earlier, DHER has been seen primarily as the executing agency for small-hydro development, the overall planning function being assigned to DGE. In practice, until now, the rural electrification sector of DHER has performed the following functions:

- planning of small-hydropower development (partial; cf. DGE, REGIDESO);
- design of lay-out and systems of power stations (most design work contracted out);
- construction, including procurement of equipment;
- supervision of construction contracts (let to religious missions);
- maintenance (not systematic);
- technical assistance (mainly to missions; not systematic);
- supervision (in connection with DGE) of private initiatives (i.e., the missions) in small-hydro, including granting of permits; and
- coordination of activities with DGE.

Functions which DHER has not been called upon to perform until now include primarily—

- design and fabrication of hydroelectric equipment;
- operation and maintenance of small-hydro plants (so far run mainly by missions);
- training of personnel (other than simple OJT);
- promotion of rural electrification, including market development, and information/extension work;
- financial planning and management (tariffs, billing, record keeping, accounting, consumer credit, etc.); and
- hook-ups and interior wiring (usually done by MTPEM or REGIDESO electricians seconded from provincial centers).

In the performance of these functions, DHER has been handicapped or impeded by the following problems:

	1982 (actual)	1983	1984	1985	1986	1987
Electro-mechanical engineers	2	3	3	3	3	3
Civil engineer, construction	0	1	1	1	1	1
Hydro-geologist	0	1	1	1	1	1
Industrial engineer, electrical distribution and end-uses	0	1	2	3	3	3
Electricians	2	5	10	15	15	15
Topographers	2	5	5	5	5	5
Mechanics (hydroelectric)	0	3	5	7	8	8
Total	6	19	27	35	36	36

Table 1. Staff requirements proposed by DHER for Fourth Five-Year Plan.

- insufficient qualified personnel; the execution of projects during 1978-82 has been greatly delayed, primarily by insufficient technicians and foremen at the construction sites; the small professional staff has been overburdened by the number of projects;
- inadequate stocks of tools and materials, primarily basic electrical equipment such as cables, wire, switches, breakers, meters, etc.; also cement, which is imported in bulk and allocated among the various Ministries, often at inappropriate times;
- lack of transport, primarily dump trucks and cars/vans for personnel at the sites; the situation would have been worse without the expatriate advisers' own transportation;
- delays in delivery of imported materials, usually over the difficult sea-overland-lake route via Tanzania;
- inability of government to find trained counterparts to work alongside expatriate professional staff;
- loss of skilled technicians to parastatal corporations, mainly to REGIDESO (the team was advised that this problem should not be exaggerated as DHER as the civil service offers better job security and other fringe benefits);
- insufficient funding; difficulty in securing external aid, allegedly because of lack of confidence in DHER as an executing agency;
- cumbersome administrative (purchasing?) procedures, especially given the small size of projects;
- jurisdictional disputes with REGIDESO, which is administratively wasteful;
- delegation of construction work to organizations (essentially the missions) not fully qualified to perform this work.

The assessment team also detected a certain vagueness in the scheduling of construction work and procurement of equipment. However, this may have been a problem of perception, as work flow charts or critical-path diagrams for key tasks may have been overlooked. Careful scheduling of work and procurement may, on the other hand, be unrealistic under the circumstances in which DHER has to work (overburdened engineering staff, uncontrollable delays in equipment deliveries, etc.).

To the specific problem areas listed above can be added the present lack of guidance from a national energy plan. There is, therefore, a certain degree of arbitrariness in the scheduling of projects (cf. Annex C). It is overall MDR's policy to promote rural electrification on social, rather than economic grounds. As noted, rural electrification is tied to the villagisation program, but this program has barely started. At the moment it cannot be expected to "lead" small-hydro development, except at certain locations.

A "Master Plan" of rural electrification based on small hydropower exists, but it was not prepared for the specific purposes of DHER/MDR. This "Master Plan for the Electrification of Rural Centers of Burundi on the Basis of Smaller Hydropower Plants" was prepared by GTZ for REGIDESO. This document is also a feasibility study ("pre-feasibility" is more accurate) for only eight centers and immediate surroundings; on the other hand, it does consider alternatives between SDH and extension of certain grids. The hydro plant for one of these centers (Ruyigi) is now being completed by DHER (first power deliveries probably by December 1982). The "Master Plan" (completed in 1981 in the context of GTZ-KfW-REGIDESO negotiations, 1975-81) illustrates the need to bring small-hydropower planning up to date in terms of well-defined rural and non-rural purposes. This document has been overtaken by events. It is not known whether the Lahmeyer International (for DGE; due April 1983) and Coyne et Belier (due 1983?) studies of Burundi's hydroelectric potential (cf. p. 3) fully meet the needs of rural development.

DIRECTION GENERALE DE L'ENERGIE (DGE)

Mandate

The mandate of DGE is defined by a Presidential Decree dated February 6, 1980 (cf. Annex B). DGE is mandated primarily to act as the central energy planning and coordinating unit of GRB. Other key elements of DGE's mandate include collection and analysis of energy statistics, overall supervision of all energy projects, and energy research. The research mandate was the main reason why DGE was not placed in the Ministry of Planning, where logically it belongs.

Manpower

In late 1982, DGE had the following professional staff:

1 Director General
2 Technical Advisers/Conseillers Techniques (projects)
1 Technical Adviser/Conseiller Technique (research and statistics)
1 Economic Adviser/Conseiller Economique (research and statistics)

The term "adviser" in this case does not connote an expatriate adviser; it connotes rather a staff adviser to the Director General. The 1982 total personnel budget (including support staff) was FBu 4.4 million (US$ 48,000).

In its 1983 budget proposal, MTPEM has asked for the following additional staff for DGE:

1 Civil Engineer (national energy planning)
1 Economist (national energy planning)
2 Civil Engineers (supervision of hydroelectric projects)
1 Electromechanical Engineer (ibid.)
2 Physicists (research)
1 Economist (research)
1 Technician (research)

The proposed total 1983 personnel budget is FBu 11.1 million (US$ 120,000), a 150% increase over the previous year's personnel budget. So far, no one person at DGE has been concerned exclusively with small hydropower. One is foreseen. Even if the 1983 requests are approved, the professional staff of DGE will still be woefully inadequate to this agency's broad mandate. This is particularly true of national energy planning (macro-hydro, small hydro, peat, energy forestry, unconventional renewable energy) and of energy research, conventional and unconventional. DGE should also be concerned with the environmental aspects of energy developments, in collaboration with the Institut National de la Conservation de la Nature. A further planning task should be the standardization of all voltages, electrical equipment, etc. used by DHER and REGIDESO.

Functions and problems

DGE is a new and badly understaffed organization which has tried as best as it can to exercise its functions. It seems to have concentrated its limited resources on its coordinating and supervisory tasks.

Insofar as small hydropower is concerned, DGE has examined project plans transmitted to it by DHER from the standpoint of the national energy interest, has approved these plans, and has followed developments abroad in this field. Two of its Technical Advisers attended the Small-Scale Hydropower in Africa workshop cosponsored by USAID, NRECA, ADB, and UPDEA held in early 1982. In 1983, DGE hopes to have an Energy Research Center operation. DGE has stated that this Center could eventually conduct research on micro-hydro on the basis of informal collaboration between DGE and DHER. The assessment team suggests that research on small-hydro equipment should be restricted to non-electrical equipment (primarily artisanal fabrication of turbines) for micro-hydro plants of under 50 kW installed capacity.

Relations between DGE and DHER appear to be good. The two organizations meet two to three times a year in coordinating meetings. Presumably contracts at the individual level are more frequent. As noted DGE has been unable to provide DHER with broad policy-planning guidance. DGE is well aware of this problem.

Theoretically, DGE can decide that REGIDESO should extend a power line from one of its grids into a rural area where a small-hydro plant (i.e., a DHER investment) seems inefficient. Conversely, DGE can prevent REGIDESO from taking over a plant of under 250 kW capacity from DHER. In practice, at the moment it appears that such questions are more likely to be decided at the Ministerial level (MTPEM; Planning) or even by Cabinet.

REGIE DE PRODUCTION ET DISTRIBUTION D'EAU ET D'ELECTRICTE (REGIDESO)

Mandate

REGIDESO, the parastatal water and power authority, was established in 1968 by a law that nationalized a former Belgian private utility. The mandate of REGIDESO is to provide water and power on a commercial basis to the entire country under a monopoly.

As noted earlier, REGIDESO's monopoly was restricted with the creation of DHER. However, REGIDESO confirmed that it is not bound by an "artificial" lower capacity limit (250 kW), nor by any geographical restrictions on its activities. It claims that the division of tasks between it and DHER occurs "naturally" or pragmatically by means of discussions and negotiations. Basically, REGIDESO is interested in serving only customers "who can pay". It acknowledges the need to distinguish between strictly commercial electrical service and rural electrification, and the existence of gray areas between the two. On the other hand, it is in principle opposed to "free" power and to the connection of unmetered users.

REGIDESO is against any rigid division of responsibilities between it and DHER, as it would lead to inefficiencies. It believes that the general interest is served by REGIDESO taking over plants with commercial customers (e.g., Ruyigi, cf. p. 8), as it would relieve the government of the burden and expense of maintenance and customer service. Payment for such plants are seen as transfers of funds from one branch of the government to another, and thus, by implication, pointless.

Manpower and functions

It is beyond the scope of this report to examine in detail the staffing and operations of REGIDESO, as much of them concern larger hydro and urban water supply. The basic information given below is intended to provide perspective on the size and capabilities of this utility, which is the main source of hydroelectric expertise in Burundi.

The electrical department of REGIDESO has a total staff of about 200, supported by another 200 employees common to the entire organization. The electrical department has a total management/professional staff of 12, of whom at least 5 are engineers. GTZ is providing long-term technical assistance to REGIDESO; in late 1982, six German engineers were assigned to the utility. This number was considered too small for the advisory tasks required.

The operating/maintenance departments of REGIDESO are reported to be overstaffed in some directions and understaffed in others, but the assessment team was not able to confirm or deny this opinion. An objective assessment of REGIDESO's pool of skilled technicians would be useful in light of the country's need for trained manpower, additional trained technicians, and for in-country on-the-job training (OJT).

REGIDESO has now (late 1982) five hydroelectric plants either in operation or under construction. They range in installed capacity from 240 kW (Kirundo) to 8 MW (Mugere). It has a further three domestic plants (2.4-18 MW capacity) in the planning stage (cf. Annexes D and E). REGIDESO receives electricity from the Rusizi I plant in Zaire over a 70 kV, 112-kilometer line with a maximum capacity of about 9 MW. It provides some of the maintenance for this Zaire-owned line. The utility also operates a number of diesel generators of up to 5 MW individual capacity.

INSTITUTIONS BELOW THE NATIONAL LEVEL

Engaged in small-hydropower development — the missions.

The important role played by the religious missions in initiating, financing, operating and maintaining small-hydro plants has already been discussed. The missions will continue to play this role in the foreseeable future, as DHER does not have the resources to assume all their functions, let alone buy the plants.

The GRB is understandably keen to exercise its control over public water and other resources, and to extend the scope of rural electrification. It should, however, continue to encourage the initiatives of the missions, and accept their willingness to operate and maintain small-hydro plants. To do otherwise is to place an unnecessary burden on government finances and services. Aside from overall planning and licensing, the role of DHER in this partnership is to assume design and construction leadership so as to ensure a better fit between design, equipment, and hydro potential. Overhaul (as opposed to routine) maintenance of mission-owned plants in time should also be taken over by the Bureaux Régionaux of DHER (cf. pp. 17-21).

Potentially relevant to small-hydropower development

Provinces and Communes

Administratively, Burundi is divided into fifteen (eight until May 1982) provinces headed by an appointed Governor. The Governor is assisted in his functions by representatives of the Ministries of Public Health, Agriculture, Education, and Interior. Whenever there is some construction underway, there may also be a temporary representative from the Ministry of Public Works (MTPEM).

In discussions, both DGE and DHER could conceive of the provinces assuming certain functions (mainly maintenance and financial management) related to SDH. However, DHER (and the authors of this report) has (have) concluded that the foreseeable small-hydro network is insufficiently dense to warrant decentralization of functions to the provincial level. Bureaux Régionaux regrouping certain provinces (cf. p. 10) seem to avoid the duplication and overhead caused by excessive decentralization. The next-lower level of government, the arrondissement, is not considered relevant for roughly the same reasons as the Provinces.

The commune (rural and urban municipality) is perhaps the key unit of local government of relevance to future rural electrification. There are 79 communes in Burundi. Each is headed by an administration communale, again appointed by the central government. At the moment, they perform simple tasks (road maintenance,

record keeping, etc.). The communes may eventually have a role in small-hydro development and rural electrification (billing, damage reporting, routine maintenance, etc.; cf. pp. 17, 19), although perhaps not for another five to ten years. There are also precedents for the provision of free labor for local community projects in Burundi. However, except in cases of genuine local initiatives, the use of free labor in rural electrification is not recommended.

There are other local levels of government below the commune (zones, colline, sous-colline); there are also party cells at the lowest level) but, for the foreseeable future, decentralization of small-hydro functions to the commune would seem sufficient. There is no question, however, that in a massive program of rural electrification, the local leadership (Chef de Zone, Chef de Colline, Umushingantahe or elders of the sous-colline, and party officials) should be involved in information, extension, and taking a lead in organizing the activities of the local community.

Cooperatives

Burundi has over one hundred farm and other cooperatives established and regulated under a law on cooperatives (Decret Loi No. 1/3 du 4 fevrier 1981, portant Statut General de la Cooperative au Burundi). As elsewhere, the performance of cooperatives has varied, depending on local leadership, outside assistance, attitudes and management skills (cf. SOMEBU, 1981). There are now no electric cooperatives in Burundi.

The cooperative form should be retained as an option for local initiative, ownership, operation and other functions in small-hydro development (cf. Fig. 3). The cooperative has, of course, the crucial advantage of encouraging local initiative, promoting vested interest in efficient operation, and of retaining benefits in the local community.

Traditional structures

Conversations with GRB officials and knowledgeable expatriates revealed a strong consensus that there are no traditional structures of potential interest to small-hydropower development. A traditional social unit, the rugo is a system of adjacent homesteads/cattle corrals organized around the extended family. The rugo has disappeared from or is disappearing in parts of Burundi. The colline (cf. also administrative colline) is sometimes referred to in terms that imply a social organization, but in effect it seems to be no more than a convenient geographical designation. In hilly Burundi, a particular colline (hill) may support a number of households, including rugos, but these households may share space and little else. They may even be competitive or antagonistic. Burundi rural society is highly individualistic, and the dispersed settlement pattern reflects this individualism. As noted, communal life is now being tried in parts of the country by means of the villagisation program. It is government rural-development policy to integrate new services, such as electrification, into modern structures.

REDEFINITION OF SPHERES OF COMPETENCE OF DHER AND REGIDESO

It is suggested that the respective spheres of competence of DHER and REGIDESO be redefined as follows:

- the upper limit of installed capacity for DHER should be retained at 250 kW; in the opinion of the assessment team, this limit was probably set too high given the resources of DHER; it is known that between a capacity of 50 and 100 kW an important threshold in technical-management complexity is passed and, according to some sources, again beyond a capacity of about 125 kW; however, in the light of DHER's construction plans, it would be awkward to revise the 250 kW limit now;
- the lower limit of installed capacity for REGIDESO should also be 250 kW, except under the circumstances indicated below;
- the government (presumably the Ministries of Planning, Rural Development, TPEM, and Interior among others) should define "urban" centers or zones where REGIDESO has exclusive jurisdiction regardless of installed capacity; by implication, then, the rest of the country would be subject to rural-development policies, including small-hydro electrification by DHER; this geographic zonation will have to be revised periodically (every five years?) in order to take into account the growth of rural centers; this zonation should also not be so rigid that it leads to inefficiencies; for example, DHER should be allowed to sell surplus plants located near urban zones to REGIDESO; similarly, in some areas it may be more efficient to extend a REGIDESO transmission line into a rural area than to develop another small-hydro plant; these deviations from the norm should be subject to planning and negotiations between DGE, DHER and REGIDESO;
- ultimately, the respective tasks of DHER and REGIDESO should be clearly spelled out by a national energy plan.

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STRENGTHENING OF NATIONAL AND SUB-NATIONAL INSTITUTIONS

Functions

The functions that are to be performed as part of a country's small-hydropower program depend on the nature of that program and on the assumptions concerning its future development. In the case of Burundi, the functions listed and their division among various levels of government in a proposed institutional framework for small hydropower (Fig. 3) are based on the following assumptions:

- the present rate of investment in, and construction of, small-hydro plants will continue until at least the late 1980's, by which time there will be 25-30 plants (both DHER- and mission-owned) in Burundi;
- DHER will adopt tariffs for institutional users of electricity in the near future (one to two years);
- there will be a commitment to place DHER's small-hydropower program increasingly on a self-supporting basis;
- DHER will establish Bureaux Régionaux (primarily for construction support and maintenance) during 1983-87 or by 1990 at the latest;
- extensive rural electrification involving the hook-up of individual households and farms will occur, if at all, beyond 1990 or even 1995;
- the delegation of certain functions (e.g., operation, damage reporting, customer relations, billing) to the local level is a desirable objective, but this delegation is not likely to occur before 1990 or even 1995 (religious missions excepted);
- because of scarce manpower resources, certain functions (primarily technical ones)

will be retained centrally or regionally regardless of the formation of rural electric co-operatives or other local utilities.

The proposed institutional framework shown in Fig. 3 is thus believed to reflect present and foreseeable circumstances in Burundi. From a theoretical standpoint, it is not an ideal framework because the functions are split among several agencies at three different levels of government. The potential problems associated with split functions are well known-poor coordination and communications, rivalries, slow responses up and down the hierarchy, and indifferent performance when control or ownership are remote. However, in Burundi over the next decade or so, it is unrealistic to expect the formation of rural electric utilities capable of integrating all or most of the functions listed in Fig. 3. It bears repeating that Burundi's small-hydropower program over the medium term will consist of a maximum of 25-30 plants serving institutional users and few rural households. Given this scope and scarce financial and staff resources, a concentration of functions at the national level and a gradual delegation of selected functions to the regional and local levels are inevitable. On the other hand, it is possible that this delegation of functions could be accelerated with the creation of cooperatives as rural utilities. Even with cooperative utilities, it is foreseen that functions such as system design, construction, equipment procurement, and overhaul maintenance would be retained at the central or regional levels.

As indicated in Fig. 3, the present (late 1982) small-hydropower program consists primarily of investment, planning, systems design, equipment procurement, construction, and some maintenance performed centrally by DHER, and operation, financing, and routine maintenance assumed locally by the missions.

The main gaps include systematic overall planning, financial management (other than investment planning), systematic maintenance and other technical assistance at the central level (DHER), and a total lack of construction support, overhaul maintenance capability, and other functions at the regional level. Aside from the missions, there are now no local structures in a position to initiate and support rural electrification, assuming this were possible today in terms of load, rural purchasing power, and other requirements.

The gaps noted are, of course, in relation to the overall framework for small-hydropower development proposed in Fig. 3. As discussed previously (cf. p. 8), many of the functions indicated in Fig. 3 have not until now been part of DHER's mandate; this is particularly true of functions related to financial management. The vacuum at the regional level is to be filled by the Bureaux Régionaux proposed for implementation during 1983-87 or perhaps later.

Burundi's small-hydropower program has, until now, focused inevitably on construction. Even in that sector, however, a critical gap has been in construction follow-up and supervision. This gap has been due to insufficient personnel (inspection engineers, technicians, foremen) and to difficulties with transport and communications. As noted, there is a complete lack of decentralized construction support and supervision, and even minor tasks have had to be carried out from the central office in Bujumbura. DHER has also been unable to provide effective technical assistance to the missions (design, overhaul maintenance, retrofit in some cases), again owing primarily to lack of personnel. It is illustrative of this problem that missions often turn to outside experts (foreign aid missions, visiting experts) for this assistance, bypassing DHER.

Manpower requirements

If the proposed overall framework for rural small hydropower and the assumptions on which it is based are accepted, several new or redefined staff positions are required to perform the various additional functions. In the case of DHER, the new staff positions listed below are either in addition to the staff requirements already submitted by this agency for 1983-87 (cf. Table 1, p. 11) or redefinitions of some of the latter. All staff requirements are exclusive of expatriate personnel. It should be emphasized that, even if the 1983-87 requirements are met, DHER will still face a shortage of senior Civil and Electrical Engineers, made up in part by expatriate staff.

LEVEL	NATIONAL		REGIONAL	LOCAL		
INSTITUTION	DGE	DHER	REGIONAL OFFICES (DHER)	COMMUNES	MISSIONS (Owners)	COOPS (Owners)
FUNCTIONS	1. National energy planning, including role of SDH; 2. Research, incl. microhydro nonelectrical equipment design & artisanal fabrication (≤ 50 kW)	1. Technico-economic-financial planning of SDH in coord. with DGE and overall rural development; 2. Lay-out/ systems design; 3. Equipment procurement; 4. Construction 5. Supervision of maintenance, management, & customer service; 6. Regional/ national coord. and standardization; 7. Training of central and regional personnel 8. Tariffs, in coord. with Min. of Commerce & Industry/Fin.	1. Overhaul maintenance for all plants; 2. Construction support, incl. hook-ups; 3. Financial management for region, incl. accounting & records; 4. Analysis of market trends & market development; 5. Financial supervision of co-ops and missions with non-mission users; 6. Training of local maintenance & management personnel; 7. Regional consumer credit office.	1. Operation 2. Routine maintenance; 3. Damage reporting; 4. Billing and bill collection; 5. Customer relations; 6. Basic record keeping, incl. demands for hook-ups.	1. Operation 2. Routine maintenance; 3. Financial management; 4. Fault/ damage reporting to Regions; 5. Service to non-mission users in accordance with financial agreements reached with Regional Offices	1. Operation; 2. Routine maintenance; 3. Financial management, incl. records, accounting, credit; debt service and repayment; 4. Fault/ damage reporting to regions; 5. Customer relations and market development.

Fig. 3. Proposed institutional framework and division of functions for rural small hydropower in Burundi over the next 5-10 years. NOTE: Boxed functions are those that are performed now (late 1982), although not necessarily fully or systematically.

At least one additional senior expatriate Civil/Electrical Engineer is urgently needed for 1983-87 to sustain the current and planned construction program.

In the case of DGE, no new position is proposed in addition to staff requirements (of relevance to the small-hydropower program) already contained in the 1983 MTPEM budget. The other professional staff requested by DGE in the 1983 MTPEM budget (cf. p. 12) is not directly relevant to the small-hydropower program.

Staff positions required to be filled within the next one to two years, regardless of assumptions, are indicated with an asterisk (*).

Level	Institution	Staff required and comments
National	DGE	1* Energy Engineer for national energy planning; already requested in 1983 MTPEM budget
		1* Energy Economist/Planner for national energy planning; already requested in 1983 MTPEM budget
		1* Civil/Electrical Engineer familiar with small-hydro planning and construction to oversee this planning and construction on a part-time basis; could be one of three engineers requested in 1983 MTPEM budget for "supervision of hydro-electric projects"
		1 Mechanical Engineer <u>if</u> DGE's Energy Research Center decides to experiment with the design and fabrication of micro-turbines (less than 50 kW); could be the same Electromechanical Engineer requested in the 1983 MTPEM budget
	DHER	1* Energy Economist/Planner for the economic analysis of small-hydro investments, loads and market development; coordinates planning with DGE and with DHER's Conseil Consultatif of DHER (cf. Annex A) and with DGE's national energy planners; new position, needed within next two years
		1* Hydro Engineer/Planning for the technical evaluation of small-hydro potential, loads, transmission lines, and energy alternatives; coordinates planning with DGE and REGIDESO; could be the same person as the "Industrial Engineer" requested in the submission for 1983-87
		1 Utility Finance/Management Specialist to set tariffs, establish accounting systems, and manage revenue funds; may eventually supervise Financial Managers at the regional levels; coordinates activities with other Ministries concerned with financial planning; new position, needed within next one to two years <u>if</u> DHER adopts tariffs for industrial users
		1* Maintenance Supervisor/Instructor; coordinates maintenance with engineering staff; orders and monitors spare parts, eventually in collaboration with Overhaul Maintenance Specialist(s) at Bureaux Régionaux; will eventually train and supervise regional maintenance personnel; new position, but filled by one of the electricians proposed for 1983-87

		1	Personnel Management/Training Specialist; acts as supervisor of training and qualification standards within DHER, including Bureaux Régionaux; new position, needed primarily once Bureaux Regionaux are established, probably by late 1980's
Régional	Bureaux Régionaux of DHER	3*	Construction Support/Overhaul Maintenance Specialists for both turbine and electrical equipment; new positions, but from pool of electricians/mechanics requested for 1983-87
		3	Management/Financial Specialists; to organize and manage records, accounting, disbursements, credit, etc. and supervise electric cooperatives and those missions that sell electricity to non-mission users; monitor market trends and develop new markets in cooperation with DHER's Economist/Planner and Finance/Management Specialist; new positions, but probably not needed before 1990 because of small scope of DHER's financial activities
		3	Training Officers; to train local maintenance and management personnel; should also be qualified to organize information/extension programs for rural electrification; new positions, but probably not needed before 1990 because of limited scope of rural electrification
		3*	Linesmen, also responsible for hook-ups; new positions, needed immediately from pool of electricians requested for 1983-87
Local	Communes	-	Local routine maintenance personnel, part-time, trained by Bureaux Régionaux
		-	Local rural electrification managers, full- or part-time, depending on the scope of services provided; in charge of billing, simple record keeping, customer relations, and damage reporting; trained by Bureaux Régionaux
			All positions at the commune level are new, but will not be needed until the functions mentioned above are delegated to this level; this is not likely to occur before 1990 or even 1995.
	Cooperatives		Same as above, except that the Financial Manager is likely to be a full-time employee also responsible for financing, debt service, market development, and the other financial management functions of a cooperative; the formation of rural electric cooperatives is not likely to occur before 1990 or even 1995 because of the lack of, or small number of, individual electricity users in rural areas

Training Requirements

The training requirements given below assume that the staff already requested in DGE and DHER budgets is not yet available, and must be trained. Positions deemed to be needed within the next two years are marked with an asterisk (*).

Institution	Position	Training Required	Order-of-magnitude costs, US$ (include salary, travel, tuition, and per diem
DGE	*Engineer, national energy planning; sent 6-12 months to foreign national energy authority or large private utility engaged in coordinated planning of various forms of energy;	Graduate Engineer, to be	20,000-38,000
	*Economist, national energy planning	Graduate Economist, to train with national energy authority or large private/para-statal utility engaged in comprehensive energy planning; 6-12 months	19,000-37,000
	*Civil/Electrical Engineer, to become familiar with small hydropower planing	Graduate Engineer, to be sent 2-3 month to country with active small-hydro-power program (e.g., Nepal, Thailand, Philippines)	6,000-9,000
	*Mechanical Engineer, to familiarize himself with both industrial and artisanal micro-turbine design and fabrication	Graduate Engineer to visit turbine manufacturers in both developing country (e.g., Pakistan, Nepal) and developed country, 2-3 months	8,500-18,000
DHER	*Energy Economist/ Planner	Graduate Economist, sent to country actively planning small hydro (e.g., Philippines) to work alongside local staff; 6-8 months	20,000-29,000
	*Hydro Planning Engineer, SDH	Graduate Engineer, same as above	20,000-30,000

DHER (cont.)	Utility Finance/ Management Specialist	Graduate Economist or Bus. Administrator sent to developed country, OJT with utility, plus selected courses with university or energy foundation association, 6-12 months	20,000-40,000
	*Maintenance Supervisor/ Instructor	Experienced automotive mechanic or electrician; to be trained OJT at small hydro plants in Burundi by tech. reps. from manufacturers of turbine/ electrical equipment; 2-3 months,.	10,000-12,000
	Personnel/ Management Training Specialist	Business Education graduate ideally, secondary business school graduate; to train with Burundi corporation, 4-6 months	800-1,200
Bureaux Régionaux (DHER)	Construction Support/ Overhaul Maintenance Maintenance Specialists, 3 x	OJT by the Maintenance Supervisor/Instructor mentioned above; short course at new mentioned above; short course at new Technical School in Gitega, and hands-on maintenance at various sites; 2 months, initial training only	1,550-3,000
	Financial/ Management Specialists, 3 x	Accountants or other graduates of secondary business school; 3-6 month OJT with state corporation, bank or branch of government; 2-3 month course (not continuous) given by DHER Personnel/ Management & Training Specialist	800-1,200

Bureaux Régionaux (DHER) (cont.)	Training Officers, 3 x	Graduates of Normale or secondary business school; trained by DHER's Maintenance Supervisor/Instructor and by Personnel/ Management Specialist	—
	*Linesmen, 3 x	Trained OJT by REGIDESO, 2-3 months	1,000-1,500
		TOTAL	127,600-220,100

Training programs must take into account the potential loss of skilled personnel to other agencies. This problem can be solved in part by requiring staff who train under contract (especially abroad) to serve a minimum time with DHER or DGE. Salaries of DHER and DGE could be revised to make them more competitive with those of REGIDESO. As noted earlier, employees of DHER and DGE could be made more aware of the fringe benefits (job security, etc.) associated with government service.

FINANCING DURING 1978-82 (THIRD FIVE-YEAR PLAN)

During 1978-82, a total of about FBu 175 million (US$ 1.9 million) was to be invested in small-hydropower plants, including the cost of low-voltage grids at Giheta, Bubanza, and Kigwena. As mentioned earlier, this investment was not a systematic part of the Third Five-Year Plan as DHER did not become operational until early 1980. The construction of eight plants was initiated and work on one of these was completed during this period. Three of these plants, however, were financed privately by NGO's.

By source, these investment funds (including private ones) break down roughly as follows:

- NGO's — ca. 35%
- State budget — ca. 34%
- FED/EDF — ca. 24%
- Fonds Blé et Farine — ca. 7%

The Fonds Blé et Farine is a bilateral scheme (Belgium) whereby free wheat and flour are made available to local NGO's for sale, and proceeds are used for a variety of local initiatives. FAC (France) has also contributed an unknown amount towards the construction of one small-hydro plant (Giheta).

The percentages given above should be regarded as indicative of the main sources of funding. Absolute amounts derived from these percentages could be inaccurate. For example, FED/EDF does not contribute funds for small hydro as such, but only in the context of its "micro-projects" program (Micro-Réalisations; Chapter 12 of the Lome II Convention of 1979), which includes many other local initiatives. Thus the total FED/EDF contribution to the small-hydro program seen by the team (FBu 43.2 million) may not have been wholly devoted to this program. FED Micro-Projects rest on the principle of local initiatives to meet locally felt needs, with the FED, the central host government, and the local community each contributing a third of the total cost. In practice, FED usually contributes (e.g., Kigwena, Bubanza, and Ryarusera installations) in the 40-70 percent range, and the local communities 10-15 percent. The leading role of DHER in small-hydro development, particularly the retention of control over the plants, is technically in violation of the spirit of Chapter 12 of the Lomé II Convention. However, it reflects institutional weakness at the local level (cf. pp. 17-18) and the now inevitable concentration of technical capabilities at the national level (i.e., DHER).

FINANCING SOUGHT FOR 1983-87 (FOURTH FIVE-YEAR PLAN)

The investment program proposed by MDR/DHER to the Ministry of Planning for small-hydro development during 1983-1987 is as found in Table 2.

To this total of FBu 470 million (US$ 5.2 million) must be added FBu 200 million (US$ 2.2 million) for tools, transportation, instruments, and materials, of which over 80 percent are earmarked for the small-hydropower program alone. An additional FBu 100 million (US$ 1.1 million) is budgeted for photovoltaic power units (for schools and dispensaries), biogas units (arid Mosso region), and solar pumps top replace manual and diesel pumps (Imbo and Mosso plains). Thus a total of US$ 8.5 million is proposed for rural energy in 1983-87.

As of November 1982, the specific source(s) of the funds requested had not yet been identified. The planning document assumed, however, that the bulk of the capital investments would again be provided by external sources. The investment program is still, of course, subject to modification and approval by the Ministry of Planning.

In general, DHER now absorbs about one-third MDR's total budget. This proportion is rising, as DHER is a priority branch of this Ministry.

	1983	1984	1985	1986	1987	Total
Small-hydro plants	50	70	80	60	40	300
Inventory of small-hydro potential and feasibility studies	5	10	10	10	15	50
Low-voltage grids	20	20	25	30	25	120
Total	75	100	115	100	80	470

Table 2. Small-hydro investment program proposed by MDR/DHER for the Fourth Five-Year Plan (in FBu millions).

OPTIONS FOR A SELF-SUPPORTING SMALL-HYDROPOWER PROGRAM

Users' fees

For the moment, power to be delivered from DHER plants will be "free". The main users starting will be missions, schools, hospitals, military camps, and other institutions. No rural households will be connected initially. Thus, "classical" rural electrification, in the sense of bringing electricity to many rural residents, farms, mills or other small rural enterprises, has not yet occurred in Burundi and is not likely to occur for another 5-10 or more years. As a result, the discussion of special tariffs for individual rural households concerns a financial system that may not be introduced for many years. It will be one of the tasks of the Energy Economist/Planner at DHER to determine at what point individual users' fees are justifiable in the light of the number of users and of the overhead created by the local/regional financial management required to administer fees (cf. Fig. 3).

In the meantime, however, institutional recipients of DHER electricity could be charged the standard national tariffs (FBu 7.6/kWh basic; adjusted rates for industrial users). For example, the Ministry of Defense is already charged for electricity and peat delivered by REGIDESO and ONATOUR. Virtually all mission stations who might tap onto a small-hydro grid are already covering the costs of diesel-generated electricity and should, therefore, continue to have the resources to cover any consequent costs that might be incurred. In addition, some missions already charge mission staff residing on the station for the electricity they consume.

The hook-up of individual households in rural centers and the introduction of fees will have to occur gradually. The sequence described in the following paragraphs might be envisioned.

Newly-connected users are allowed a grace period of a half to perhaps a full year before they would be charged for electricity. This grace period would permit prospective customers unfamiliar with electricity to determine for themselves whether electricity can be of net benefit to them. Initially, it would probably be unrealistic to expect such households to pay for the hook-up though the costs could be built into the tariff structure.

In a second stage, users could be charged at flat, nominal rates to simplify billing and to avoid metering. Current limiters might be considered as an alternative to metering. Were such a flat rate to be introduced in late 1982, it might be in the FBu 500-1,000 (US$ 5.50-11.10) a year range for lighting only. Discussions showed this rate to be within the purchasing power of rural residents. For the sake of comparison, in 1982:

- the retail price of 10 liters of lamp kerosene was about FBu 700;
- in urban areas, 2 x 50 W lightbulbs x 4 hours daily = 12 kWh/monthly, equivalent to FBu 91 monthly or FBu 1,092/year;
- some missions charge FBu 25 per medical visits;
- at least one Mission (Butezi) charges FBu 3/kg (FBu 20 per family per week, average or FBu 1,040/year) for grain milled at the mission.

Disposable annual household incomes in relatively prosperous rural areas (Murago and Minago) have been found to exceed FBu 8,000 (US$ 89). In a poorer area (Burambi), however, annual expenditures of about FBu 26,000 (US$ 289) apparently equal annual cash incomes (cf. SOMEBU, 1981).

The flat rate might then be increased to FBu 1,500-2,000 (US$ 17-22) a year if small appliances (e.g., hot plate, kettle) are added.

Metering would be introduced in the case of households or small businesses likely to exceed, say, 100 kWh/month. These users might then be charged the regular national tariff or slightly moderated "rural" tariffs if these are deemed to be in the interest of rural development.

At an average flat annual rate of FBu 1,000, the connection of 5,000 households would generate FBu 5 million/year gross. This is a significant amount, given the investments in small hydropower foreseen in 1983-87 (cf. above). However, in late 1982, the connection of even this small number of rural households appears to be a formidable task (dispersed farmsteads, unsuitable traditional housing, inability to pay for hook-ups and appliances, unavailability of appliances, unfamiliarity with electricity, and a reported lack of interest in electrification among many rural residents who may not even own kerosene lamps).

By about 1990, DHER could have a total installed capacity of about 1.3 MW which could translate into annual sales to institutions of at least 5 million kWh (5 GWh) of electricity. If this power were billable at an average tariff of FBu 10/kWh, DHER could generate total gross revenues of FBu 50 million. Even this optimistic assumption shows, however, that users' fees alone will be able to finance only part of small-hydro development in the foreseeable future.

Transfer payments

An argument can be made, on grounds of equity, for the annual transfer of a percentage of REGIDESO's surplus (if any) to DHER's rural electrification investment fund. REGIDESO has been relieved of the responsibility to provide high-cost electricity to rural areas, but the burden has been transferred to the State budget. REGIDESO is thus able, in theory, to generate higher revenues than if it were held to its mandate to provide electricity to the entire country.

Diversion of part of REGIDESO's surplus would require a high-level policy decision. A careful formula would have to be worked out so that the financial soundness of this utility is not jeopardized. There is no point in weakening one organization in order to relieve another financially hard-pressed body (DHER). Even in favorable years, an excessive diversion of revenue could act as a deterrent to efficient operation and investment policy of REGIDESO.

A subsidiary policy option might be to consider occasional grants from REGIDESO to DHER for purposes of rural electrification. Again, the timing and amounts of such grants may have to be decided at the Ministerial/Cabinet level.

Sales of electricity to REGIDESO

As rural electrification by means of SDH proceeds, it is possible that opportunities will arise to connect some of DHER's plants to REGIDESO's grid(s) at a reasonable cost. DHER's planning staff should be alert to these opportunities to sell surplus power to REGIDESO. The government may have to decide under what conditions this could be done and to devise appropriate legal procedures for these sales to take place.

Sale of plants to REGIDESO

As rural centers grow and REGIDESO's grid(s) is (are) extended, it is possible that some of DHER's hydroelectric plants become surplus to rural development needs. The sale of these plants to REGIDESO should then be considered in order to generate revenue for rural electrification elsewhere. Again, it would be the task of DHER planning staff to monitor such opportunities.

Sale of plants to rural electric cooperatives

Duly constituted rural electric cooperatives should be allowed to purchase small-hydro plants from DHER. Additional funds (loans) may have to be made available to the cooperatives at reasonable terms to facilitate purchases as the social capitals may be insufficient. A source of these loans might be the Banque Nationale de Développement Economique (so far most of the financial support of cooperatives has come from external sources such as UNDP and FED). The cooperatives would then reimburse DHER (Bureaux Régionaux) for overhaul maintenance and other services.

Electric-arc production of nitrogen fertilizer

DHER, in collaboration with the research staff of DGE and foreign technical assistance, should examine the possibility of developing one or more hydro sites for the production of nitrogen fertilizer by the electric-arc process (see Annex G). Though there are obstacles which will have to be overcome before more widespread use of technology, two main considerations suggest that this proposal be examined carefully. One is the availability of unused hydro potential in parts of Burundi because of low load potentials. The other is the acute need for nitrogen (and other) fertilizers in Burundi. If the high initial capital investment could be absorbed by external aid (soft loans, grants), then the country would acquire an asset of national importance. In the long run, DHER could also generate revenue from the sales of fertilizer, as well as from the sales of other goods and services produced with surplus electrical and mechanical energy from small-hydro plants (cf. pp. 38-39).

Conclusion

Under the best circumstances, it may still be impossible to place Burundi's small-hydro program on a self-supporting basis in the foreseeable future. Budgetary appropriations and foreign aid may still be necessary to ensure reasonable progress in rural electrification over the next 10-30 years. It should be a policy goal, however, to reduce contributions from these two sources as much as possible without jeopardizing the program. A reasonable target might be a small-hydropower program that is at least 30-40% self-supporting by 1990. The ultimate goal is a self-supporting program of rural electrification with tariffs that reflect its true operating costs and investment needs or some other national objective (e.g., creation of a rural development investment fund).

OPTIONS FOR RURAL ENERGY

In a country like Burundi which is well-endowed with hydropower resources, there is little question of the appropriateness of exploiting these resources to meet the energy needs of the urban sector of the population. It is easy to reach a similar conclusion regarding the suitability of hydropower for meeting the needs of the majority of the people who live in the rural areas. However, such a conclusion is not necessarily justified. The following paragraphs briefly review the possible options available for the generation of energy in the rural areas. Further, a more thorough consideration of the advantages and disadvantages of each option need be given before resources are committed to the development of any of these options.

Energy for cooking is the principal energy need for the rural population and, for this purpose, fuelwood is most appropriate source of energy. It is a "technology" with which subsistence farmers are already familiar and which is easily the least costly of the alternatives. The use of fuelwood, provided that it is accompanied by adequate forest management, has ancillary benefits at least as important as the cooking of food—forests provide ground cover, promote infiltration of moisture, contribute organic matter to soil, and stabilize mountain slopes against erosion. In countries with large hydropower resources and few remaining forests, hydropower is frequently viewed as the solution to the problem of household energy, dwindling fuelwood supplies, and environmental degradation. However, given the nature of the load associated with cooking, electricity is not a realistic form of rural household energy, even if the entire country were served by the national grid.

Secondary energy needs for development in the rural areas are those required for health care and educational facilities, for small and village industries, for food- and cash-crop processing, and for lighting. There are several options for providing mechanical and/or electrical energy to meet these needs.

Providing electrical energy through the extension of the grid into rural areas is, of itself, not impossible. A number of rural electric cooperatives in the United States, for example, have average customer densities of two to four customers per kilometers of line. However, these customers do have the financial resources to purchase and use a significant amount of energy. This is not the case in Burundi at present. Not only is the population dispersed but there is little disposable income and individual households have no real need for electricity. Consequently, grid extension is not a viable option for rural areas in the country.

Diesel-generated electricity is another option but obstacles to its use are the limited availability of fuel, its high cost, difficulty in transportation, and general lack of expertise to maintain a relatively complex piece of equipment.

In spite of their high cost at present, solar photovoltaic cells or arrays are seen by some as the solution. But even if the costs decrease to US$ 500/peak kW by the end of the decade (or greater than $2,000 per usable kilowatt), these will remain expensive. In addition, large battery banks are required to store power for use during evening hours or cloudy days, and electronic inverters are required if one is to generate standard distribution voltage. Photovoltaic arrays are appropriate where small quantities of electrical power are essential (such as for the navigational beacon located in Ruyigi), where isolation is high, and where no other economical alternative exists. On the other hand, solar thermal power can be provided at much lower cost but is of limited use in rural areas, except for special uses, such as for heating water for clinics and hospitals or for drying crops as part of cottage industries.

Biogas is another source of renewable energy which has the advantage of also producing a high quality fertilizer. However, it requires a sizable investment and sufficient dung or other

digestor feedstock not available to the average subsistence farmer. In spite of success stories emanating from several countries, such systems are often not economical and failure rates are high. The gas derived is a source of thermal energy which can be used for cooking but mechanical or electrical energy can only be obtained by using the gas in a modified internal combustion engine. This introduces another level of cost and sophistication.

Energy from the wind can also be tapped but even if the average velocities found in Burundi were suitable, energy density in wind is low and large structures are therefore necessary to harness even small amounts of power. The old Dutch windmills and the modern NASA windmills in the United States are witness to this fact. Windmills are expensive and relatively complex structures and, like photovoltaic arrays, are appropriate where small amounts of electrical power are necessary and no other more economical option exists.

Hydropower is another renewable energy found in much of the country. When considering the generation of power in, and for, the rural areas rather than for the larger rural centers, smaller decentralized plants should be considered, plants such as those presently found at a number of mission stations. These generally generate less than 50 kW and are considered as "micro-hydro" plants.

Though the turbine used to convert waterpower into mechanical power is intrinsically simple, micro-hydropower installations have also often been dismissed as inappropriate because of their cost and overall sophistication. However, as will be illustrated below, many of these arguments have, in recent years, been addressed. Costs have been markedly reduced through the use of civil works of simple designs which maximize the use of local skills, labor, and materials, reliance of local management structures, and use of more appropriate, less complex, and often locally fabricated turbines and related equipment. The cost and complexity of micro-hydropower plants can be reduced to the point that, if suitable hydropower resources exist in a country, the main requirements for widespread use of this technology are (1) developing an appropriate implementation strategy which includes productive end use as an integral component of a project and (2) setting up, or finding, an institution committed to bringing power to the rural areas for the development of these areas. Most of the other technologies have these obstacles to surmount as well as these associated with their relatively high cost and use of sophisticated equipment.

RURAL DEMAND AND OBSTACLES TO RURAL ELECTRIFICATION

Micro-hydropower plants are commonly utilized to provide electrical as well as direct mechanical power. But since hydroelectric power is generally implied when considering hydropower, it may be appropriate to briefly review rural electricity demand and obstacles to rural electrification since there affect the approach to developing the micro-hydropower resources in the rural areas.

In view of the fact that two percent of the country's population has access to electricity, the per capita electricity consumption of about 12 kWh is meaningless when planning for the needs of the rural population. Besides their energy needs for cooking, which would be extremely costly to satisfy with electricity, there are few other present needs which could be met with electrical power. There is some limited use of kerosene and other petrolum products for lighting in the evening and some use of batteries for flashlights and radios. Both of these needs could be satisfied easily with small amounts of electricity. In addition, there is the regular milling of manioc and some grain at the household level which requires considerable effort. This could be electrified but this would represent a significant considerable initial capital expense.

In addition to having little need for electricity, rural households have little disposable income to spend toward that end. A socio economic base-line study in an economically more prosperous part of the country (SOMEBU, 1981) found that an average disposable income per family was about FBu 5,000. It would be fair to assume that even this relatively low figure is not within reach of a significant portion of the rural population. It is interesting to note that even in Bujumbura where electricity is readily

available and where the disposable income is relatively high, there are fewer than 6,000 service drops (connections) in late 1982, including a large number of Europeans and businesses, in a city with an estimated 200,000 inhabitant (H. Feigl, Inq., REGIDESO, personal comments).

And finally, besides the low energy requirements of the rural population which might potentially be met with electricity and their low disposable income to pay for electricity and end-use appliances, the distribution of the population in the country presents a major obstacle to providing them with electricity. Even in rural areas of high densities (400 inhabitants/square kilometer and above), families are more or less eventually dispersed throughout the countryside. There are virtually no villages as such in Burundi. The distribution of electrical power to such dispersed homesteads, while technically possible, is not economically feasible.

SOME OPTIONS FOR DEVELOPING MICRO-HYDROPOWER RESOURCES FOR RURAL AREAS

The Burundi government's present approach to rural electrification is basically a scaled-downed version of the conventional approach used by REGIDESO to bring power to urban areas and to the smaller towns of the interior (Mugere, 8,000 kW; Gitega, 1,200 kW; Muyinga, 800 kW; Kirundo, 240 kW; and others). Thus, until now, DHER has met the more modest energy needs of rural service centers—schools, clinics, government offices, missions, and commerce—with smaller conventional plants. This is the case at sites such as Buhiga (220 kW), Nyabikere (110 kW), Ruyigi (70 kW), and Giheta (30 kW).

If the power needs of the more dispersed rural population are to be met, however, the constraints of a conventional approach become significant. As will be illustrated later, by continuing with the conventional approach to implementation and management, costs per installed kilowatt generally tend to rise as the installed capacity of the plant decreases. The financial resources to cover both the high capital and recurring costs of these plants is virtually non-existent in the rural areas. The increased logistical and staffing requirements associated with the installation and maintenance of a large number of small schemes by a central office also discourage such an approach. In addition, many countries rely on international funding institutions to provide the necessary financial capital. These institutions, however, find the financial management of such small projects unwieldly and implicitly, or explicitly, encourage the costlier, and therefore larger, most conventional projects. This is a tendency, however, that the "micro-project" provision of the Lomé II Convention (cf. Section V.A) is designed to counter.

As rural electrification proceeds to smaller and more dispersed users, it is worthwhile to consider less conventional approaches to developing micro-hydropower resources. The Government of the Republic of Burundi has already expressed an interest in the approaches used in several developing countries, especially Nepal, to exploit their micro-hydro resources for the development of the rural areas of these countries. What follows are brief descriptions of several approaches, each of which, in part, may have some relevance to the situation found in Burundi. More detailed accounts of the approaches pursued by both Nepal and Pakistan can be found in the NRECA publications, Nepal, Private-Sector Approach to Implementing Micro-Hydropower Schemes, A Case Study and Pakistan, Villager-Implemented Micro-Hydropower Schemes, A Case Study. It should be clear that no single approach described below should be adopted without considering the social, economic, demographic, and political realities as well as the level of development unique to Burundi or any other nation or area. Specific elements of some of these approaches might, of course, be extracted, appropriately modified, and then remolded into an approach which addresses conditions found in Burundi.

Nepal: a non-subsidized, private-sector approach

The need for motive power in Nepal was clearly evident. Rice had to be hulled, grain had to be milled, and oil had to be expelled from seed. These tasks had traditionally been done by the

women. Wooden waterwheels had been used by some for centuries for one of these tasks—the milling of grain. More recently, diesel and gasoline powered mills have become popular. But the fuel is expensive and difficult to transport to areas reachable only after several days' walking along narrow mountain trails.

In the 1960's, a Protestant mission group and a Swiss technical assistance group each established a financially self-sustaining machine workshop as part of its development assistance. On its own, each group set out to meet the need for mechanical power rather than to initially introduce electricity which would have been a relatively complex technology foreign to most. In the 1970's, they each developed what is now a well-engineered and tested crossflow turbine (Ossberger-type) to replace diesel engines as a source of power. They each work with entrepreneurs in the rural areas who wish to establish a mill. They fabricate and assemble the entire package which is required — turbine, penstock, and hulling, milling, and oil expelling equipment. The entrepreneur is responsible for preparing all the excavation and transporting the equipment to the site. A team from the company assists with the installation which usually takes three to four weeks. The entrepreneur pays all the costs involved, usually assisted by a loan from the Agricultural Development Bank of Nepal. The total costs (land, equipment, labor, licenses, cement, etc.) average about $8,000 for a 10 kW plant. The loan is paid back over a four-seven year period with receipts from the milling.

Only now, after successfully introducing modern turbines, are they slowly making available electrical power, primarily for mill lighting, to those who request it. The new unit they fabricate has a provision for mounting an automobile alternator. In approaching the development of the mill in this sequence, the hydropower plant first pays off for itself from the earning from milling, the owner has become familiar with its operation, and then the electricity generated is virtually free. This eliminates the common problem of trying to find an income-generating end-use of electricity where the power will primarily be used for lighting.

Nepalese have been trained to undertake all aspects of the work in these two companies and, over five years, have installed more than 120 hydropowered mills. During these five years, they have therefore installed plants with a power potential of about 1 MW (1,000 kW) at the total installed cost of about $1,000/kW with no financial subsidies. The turbines which they currently manufacture operate under heads of 2-80 meters, heads which are commonly found in Burundi, to generate power ranging from 4-70 kW. At the same time, a number of other small workshops in Nepal have undertaken fabrication of similar turbines entirely on their own. It has become, in Nepal, a technology which is contagious. These companies have also found that there is no need to search out sites around the countryside. Farmers and entrepreneurs quickly realize the appropriateness of the technology and make inquiries with the companies.

Pakistan: a community self-help approach

In northern Pakistan, three million people live in small remote mountain villages. A micro-hydro program was initiated by a professor from the local university of technology and the Appropriate Technology Development Organization to provide villagers with electricity to replace kerosene used for lighting and to provide motive power for small village industries. A crude crossflow turbine is fabricated locally and coupled to an imported generator. The villagers, working through a village leader, initiate a request for a plant, provide some of the capital and all the labor. By simplifying the design of both the turbogenerating equipment, the civil works, and the distribution and by using the villagers to implement, manage, and operate their own plant, costs are kept down to the minimum. The provincial and/or federal governments cover about 70% of the total capital costs. Villagers are usually charged a flat rate of US$ 0.50 per bulb per month for lighting which is used during evening hours. During the day, a quarter of the plants installed to date provide direct motive power to belt-drive saws, mills, lathes, grinders, and other equipment.

Over the last five years, they have installed nearly 40 plants with a total capacity of

approximately 400 kW at a cost of about $600/kW including distribution and house-wiring. The total staff for this program were two professors who contributed some of their time and a permanent field staff of two. This effort was entirely indigenous, with no overseas assistance, either expertise or funding, used.

Indonesia: a battery-charging approach

Economic development has reached such a stage in this country that, whereas a sizable number of villagers can afford some basic electrical appliances, they are not served by any electrical grid. However, many charge their motorcycle or car batteries in the town and transport them to their homes where these are used to power lights, radios, and other appliances.

A plan recently being studied considered setting up small-hydropower plants, each of which would serve several villages. Power from each plant would be transmitted at standard distribution voltage to one point in each village. A battery charging unit, run either by an entrepreneur or the community, would be installed at these points and villagers could bring their batteries to be charged on a regular basis.

This approach permits serving a wide, dispersed population at minimum capital cost. The cost of distribution to individual homes is eliminated and the cost of the battery is borne by the user himself. In addition, battery charging permits an efficient use of generating capacity since the load is averaged over the entire day and does not peak during the early hours as is usually the case. This peaking often restricts the usefulness of small plants which directly serve the consumer in his home.

Panama: a cooperative approach

Realizing that the national grid will not serve many rural communities for a long time, the institution responsible for electrification in the country (IRHE) recently embarked on a program of permitting communities to generate and sell electrical power to customers within their communities. The national utility assists the communities in installing plants, training of operators, rate setting, and obtaining loans. Once a plant is operational, it belongs to the community. They run and maintain it, and revenue collected remains within the community (except that which is necessary for loan repayment). IRHE provides labor and expertise for repairs at no cost to the community and the community covers the cost of the parts required.

ANALYSIS AND IMPLICATIONS FOR MICRO-HYDROPOWER DEVELOPMENT

If electrical energy through the exploitation of micro-hydropower resources is to be made available to the rural areas to facilitate their economic development, several obstacles must be surmounted. The first obstacle is the high cost usually associated with the exploitation of these resources. This can be surmounted in either of two ways, by either adopting various approaches to reducing the cost of this exploitation and/or by integrating productive end-uses at the conception stage of the development of each site so that income generated can cover these costs. The second obstacle is institutional, finding the appropriate institution(s) and individuals trained and committed to carrying out all aspects of a micro-hydropower program.

Capital requirements for developing micro-hydropower sites

The appropriateness of providing power to rural areas through the development of their small-hydropower resources has often been overlooked or summarily dismissed in numerous countries. This is especially true of micro-hydropower potential. One of the major factors has been the high cost usually associated with developing this potential.

Because of economies of scale, when using a single approach to developing hydropower sites, costs of small schemes have tended to be high. For Burundi, for example, the costs of constructing the plant and transmission lines at eight potential sites studied by the German Agency for Technical Cooperation (GTZ) in 1981 are plotted in Fig. 4. The trend is clear — as the installed capacity of a plant decreases, the cost per kilowatt increases. The cost of

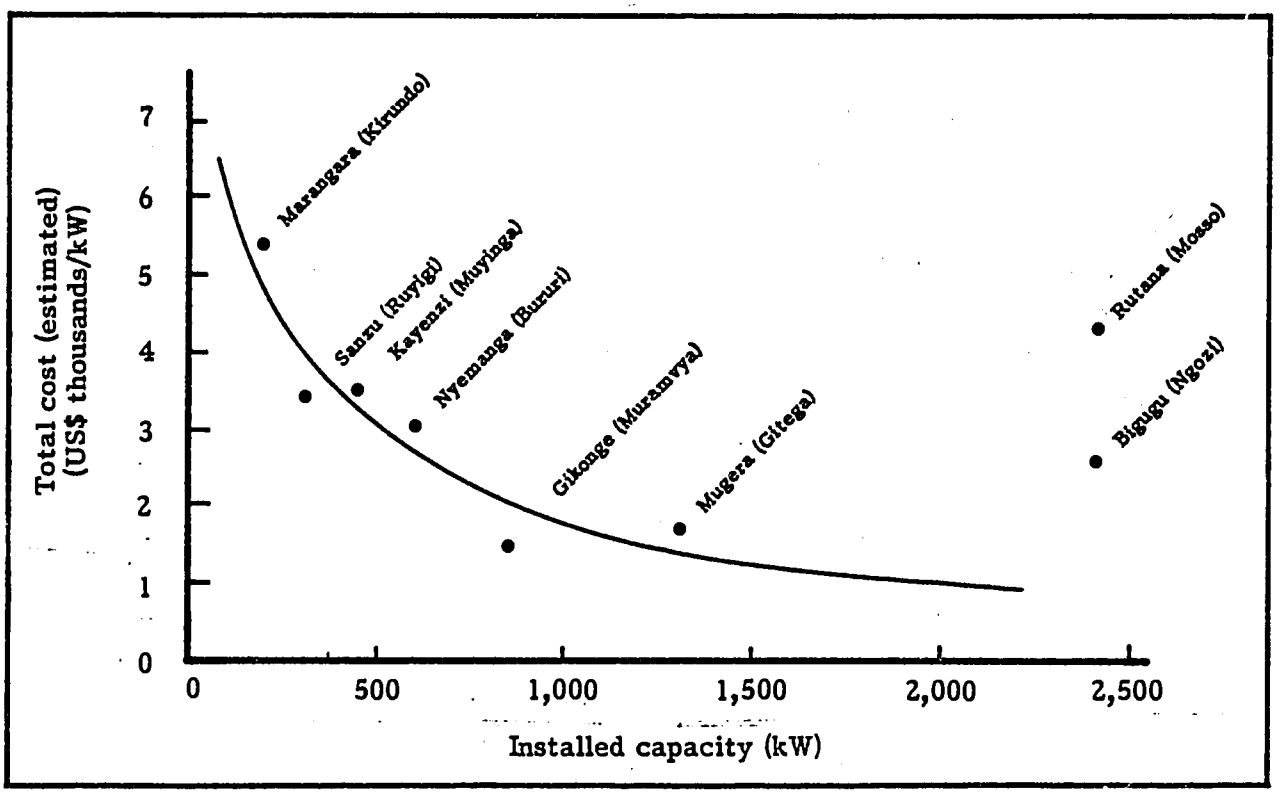

Fig. 4. Projected costs of eight hydropower schemes in Burundi (GTZ,1981)

plants proposed by DHER for the next five-year plan reinforces this trend by adding several more points at the lower end of the curve (less than 200 kW).

However, these costs assume that a common approach is used in developing these sites, that largely used in Western countries. If another approach is used, a new set of costs are encountered. For example, at the other extreme from the high costs associated with the conventional approach are the low costs of the approaches used in Nepal and Pakistan. Fig. 5 compares the cost of the conventional approach (as reflected by the costs found in the GTZ pre-feasibility study of 1981) and those of the Pakistani approach (villager-contributed labor, simple locally fabricated turbine, virtually no engineering studies, and minimal wiring standards) and the Nepali approach (as above but with a well-engineered and fabricated turbine and mechanical end use of power).

Certain aspects of the lower cost approaches, besides cost itself, might make them more attractive for Burundi. Simplifying designs reduces cost and, at the same time, increases the robustness and reliability of a system. Less can go wrong, and, when it does, it can be repaired more easily. It makes the technology more accessible to the local population and increases the chances of replication elsewhere in the country. Involving local labor on a self-help basis reduces cost to the implementing agency while also increasing the villagers' or famers' share in the project and therefore the project's viability. In-country fabrication of turbines reduces cost but also increases the benefits to the country—foreign exchange is saved, jobs are created, in-country expertise is enlarged, and repairs can be undertaken locally.

Consequently, small-hydropower schemes are not necessarily as expensive as commonly assumed. Costs are a function of the approach used in designing, implementing, and managing small-hydropower plants. They may lie on the curve representing costs of a conventional approach to their development or on curves representing a self-help approach or on curves which lie in between (Fig. 5, dashed lines). Cost, of itself, therefore, should not prove an excuse for not exploiting small-hydropower resources.

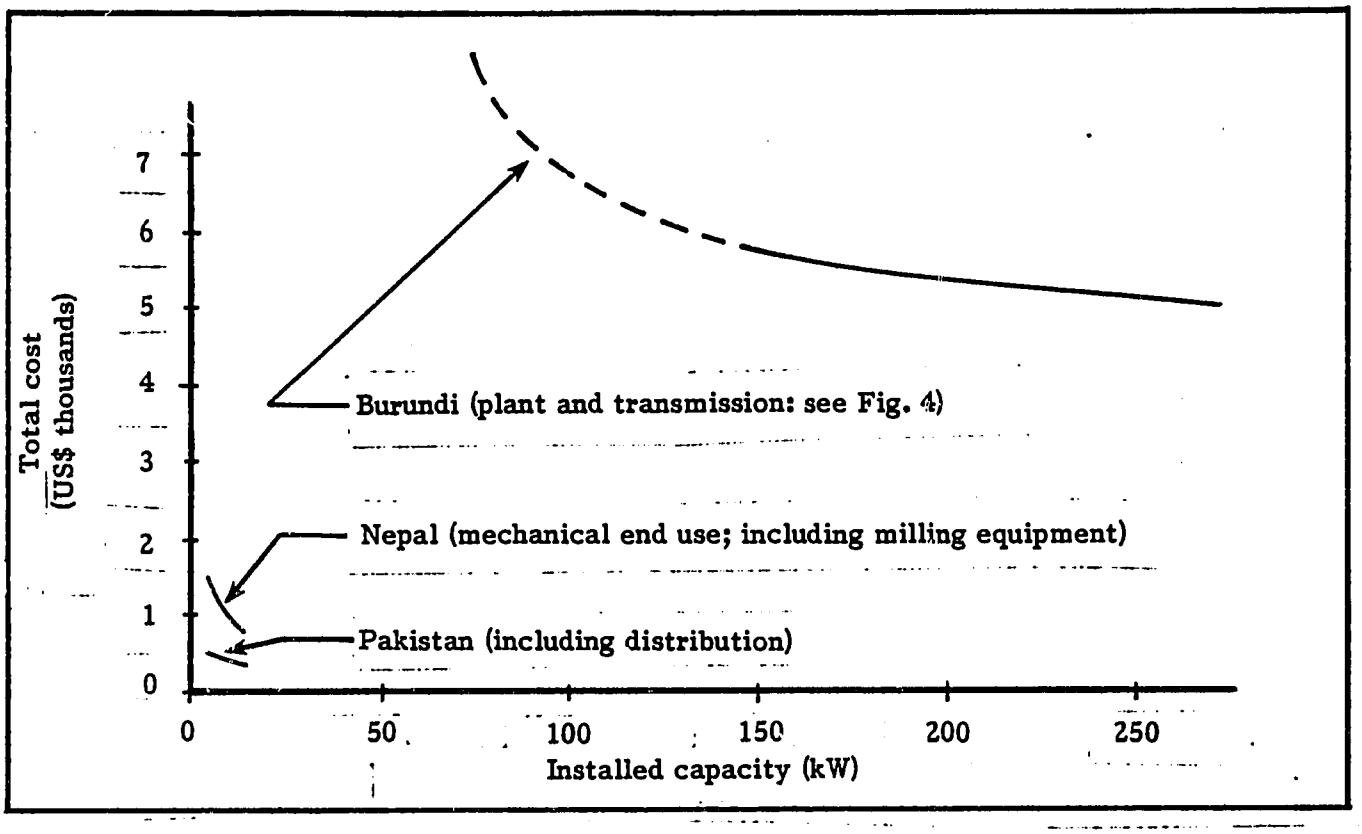

Fig. 5. Comparison of cost trends for various approaches to developing small hydropower sites.

Technical approaches to reducing costs

One of the most costly items required in developing micro-hydropower sites is the turbogenerating equipment package. This is because such packages are both imported from the industrialized countries and designed to meet the needs and conditions encountered there. It must be realized that these are not necessarily the needs of Burundi.

There are several ways of reducing this cost. Since the turbine often represents the most costly component of a turbogenerator package, the first option is not to purchase equipment from large Western companies. Their turbines are conventionally designed for a particular site, include various control mechanisms so that a range of streamflows can be accommodated, are fabricated to close tolerance, and often make use of special materials. One way of reducing cost would be to import such equipment from the developing countries, from Nepal, China, Colombia, or Indonesia, for example. This might be appropriate if only a few units are to be installed or when it is desired to first install a few demonstration units with minimum effort in order to determine the appropriateness of the technology before undertaking a nationwide program. Later, if the technology proves appropriate and the institution necessary for the implementation of such schemes on a nationwide basis has been developed, fabrication of turbines in-country can be considered. Turbines could then be designed which cater to the realities found in Burundi. Costs are reduced because turbines of less than maximum efficiency can be utilized, especially given the magnitude of the hydropower resources generally found in the country. Extensive design work to maximize turbine efficiency is often associated with turbines purchased from the West. With the lack of sophisticated end-uses in the rural areas, there is no need for the costly and complex governors found with imported units. If repairs can be undertaken locally, there is no need for the use

of costly, exotic materials as is often found with imported units.

Another way to reduce cost is to embark on local manufacture. Colombia has been fabricating low-head axial flow propeller turbines in a range of capacities. Pakistan, Thailand, Indonesia, and Nepal, for example, have been fabricating low- to medium-head crossflow (Ossberger-type) turbines for several years. Several Andean countries in South America have been casting high-head Pelton turbines for generations. Even Papua New Guinea, an unknown island a century ago, has undertaken the local fabrication of both Pelton and crossflow turbines with low-keyed technical assistance from overseas. Machine shops and a number of companies which fabricate metal products can be found in Burundi. With proper guidance, simple turbines could be fabricated in-country. Imports would then be restricted basically to steel and bearings. A number of technical training institutions and missions have facilities where turbines could be fabricated. If a hydropower plant is to be used for the generation of electrical power, as opposed to mechanical power to directly drive machinery, a generator is also required. This item will have to be imported. Though it is a fairly difficult item to manufacture, it is manufactured on a large scale around the world and is therefore inexpensive. It is the cheapest component of a turbogenerator package.

Both the turbine and generator are essentially robust pieces of equipment. Required maintenance is restricted to simple lubrication (unless sealed bearings are used), replacement of brushes (unless a brushless generator is used), replacement of belts (unless the generator is directly driven), and the very occasional replacement of bearings. For an appropriately designed system, only the replacement of bearings is clearly necessary.

However, from both the technical and cost points of view, the same cannot be said of a third component, the governor, when it is incorporated as part of a small decentralized hydropower plant. This component is normally included to control the speed of the turbine and, therefore, the electrical frequency at the generator output. It is a technically sophisticated piece of equipment whose cost is increasingly significant as the installed capacity of a plant decreases.

Several existing hydropower plants in Burundi have experienced problems with their governors. At the Mission Evangélique des Amis at Kibimba, the governor was disconnected from the system because of faulty operation and the system frequency was controlled manually at the mission itself by adding or removing ballast loads (hot water heaters). At the mission at Musongati, the governor was disconnected because, for its operation, it consumed too much of the power generated at the plant. Even with the larger (presently 800 kW) hydroelectric plant serving Gitega under REGIDESO management, operation of the governor caused excessive frequency variations. These seemed to be due to problems of improper storage and/or installation (depending upon the source of the information).

For small decentralized hydropower schemes, at least two basic alternatives to the use of a governor are available. These are the use of either an electronic load controller or manual control. Both of these options are especially suited to run-of-the-river plants, that is, plants with no storage capacity, where, for the generation of the required power, the plant needs no more water than is actually flowing in the river at the time.

In the case of an electronic load controller, the turbogenerator generates a fixed power and any excess power resulting from the difference between the power generated and that demanded by the user is sensed electronically and dissipated, usually in the resistive heating of water. A load controller has no moving parts and is a fraction of the cost of conventional governors. These are available to handle outputs of up to on the order of 100 kW, single- or three-phase. These units are relatively recent entries on the market and some have not been adequately tested under actual field conditions. One exception appears to be the unit available through Intermediate Technology Industrial Services (ITIS) of Rugby, England. Leroy Somer, a French turbine manufacturer, has also developed a load controller and one of these units is to be installed shortly at the DHER site in Giheta. But before load

controllers are used, attention must be paid to their reliability, ruggedness, and, perhaps, most importantly, options for repair.

A second alternative is to perform the above task manually, as is presently done in Kibimba, by inserting or removing loads to maintain frequency within the desired range. Though perhaps less technically attractive (i.e., it is not automatic) and less precise than either the load controller or governor, this approach has proved fully adequate, even for a variety of end-uses typically found in the Western home. This includes fluorescent and incandescent lamps, hi-fi's, blenders, washing machines, and microwave ovens.

To reduce costs and mechanical complexity of micro-hydropower plants, serious attention should be paid to developing a turbogenerator package more appropriate to the needs of Burundi. It will be difficult for a micro-hydropower program catering to the needs of, and the conditions found in, the rural areas to be viable if reliance on overseas sources of complex and costly equipment is continued. In the same manner as turbines may initially be purchased from developing countries to reduce costs, so might complete turbogenerating packages if units appropriate for conditions found in Burundi can be located.

Considerable reductions in cost and complexity can also be accomplished in cases where hydropower is used for mechanical purposes, such as milling, sawing, mechanical hot-air production for crop drying, soap-making industries, etc. With such end-uses, the expensive, often sophisticated, electric and electronic components are eliminated. A small automobile alternator could still be used to generate a small amount of power for lighting and no control equipment would then be needed.

In developing small-hydropower sites, another cost component which can be reduced is that associated with the design of their civil works. The civil works generally used in the small-hydropower installations visited in Burundi are generally extensive and substantial, with well-built masonry dams, intake structures, and power canals. The question which arises is whether these conventional and generally more costly designs were adopted because of a lack of familiarity with other options. A familiarity with designs more appropriate for small-hydropower installations is often lacking because interest in exploiting small-hydropower resources is a relative new phenomenon in economically developing nations. Consequently, more conventional designs utilized with large hydropower schemes are often simply reduced in size for small-hydropower installations. The new realities facing those developing small-hydropower resources, namely, the need to reduce cost and complexity of the technology to make it more suitable for more widespread replication in rural areas, is often overlooked.

One example of the difference in approach is in the design of the diversion structure. A dam is conventionally incorporated in a hydropower scheme either to create storage capacity and/or to increase the head available for the generation of power. However, the substantial, well-built mansory dams found in many small-hydropower installations in Burundi serve neither of these functions. These structures are simply used to divert a portion of the flow into the intake. Including a dam when it is not essential can add significantly to the cost of a small-hydropower project. It is interesting to note that the design and construction of a dam can significantly affect the cost of larger schemes as well. These costs are a major reason for the high cost per kilowatt for the two largest hydropower schemes noted on the graph in Fig. 5. The other schemes illustrated are all run-of-the-river, with no dam for the storage of water.

A design found in several schemes in the highlands of Papua New Guinea illustrates a lower-cost, less problematical design alternative. There, rather than building a concrete-masonry dam on a rock foundation, a width of the stream just below the intake is covered with a relatively thin layer of concrete or "sill". In this manner, it is not necessary to build the structure to resist large downstream forces often encountered with dams. This "sill" presents no obstacles to the flow of water. It also does not retain sediment and other debris which might otherwise have to be periodically removed from behind a dam. This "sill" across the river is sometimes slightly slanted toward the intake so that, if streamflow is very low, this flow is "funneled" toward the intake.

During times of heavy rains, the flood water overflows the entire width of the "sill" and no longer is directed toward the intake. Any debris is simply washed over.

There seems to be a need to establish a standard design philosophy for developing small-hydro projects. This should be based in part on a complete review of designs of existing small-hydropower installations in Burundi and operational and maintenance problems they face. Then designs should be prepared which can avoid or minimize these problems. If there is to be broader replication of small-hydropower schemes, there is at the same time a need to adopt designs which reduce costs and complexities of construction while at the same time adequately and reliably serving their function.

Potential loads for decentralized micro-hydropower plants

It is apparent that existing needs for electricity at the household level in the rural areas is negligible, that disposable income required to receive and pay for electricity and electrical appliances is low, and that the dispersed nature of the population discourages the distribution of power. Though villages generally do not exist, there are several cases where electrification could prove feasible.

One is in small rural centers, those often formed around the missions. Small-hydro plants could provide power for the mission, schools, hospitals and clinics, cooperatives and other small commercial activities, and government offices in these centers and, in this way, provide electricity to assist in the development of the surrounding rural areas. Many of these centers also already have some resources to contribute toward covering the cost of the electricity. This approach has already been undertaken by a number of missions and both REGIDESO and DHER are currently involved in installing generally larger plants near such rural centers.

Electrification might eventually also be feasible in areas which are "villagized" by the government. If a criteria for selection of such areas includes that they are located near potential hydropower sites and if these villages are laid out appropriately, distribution of electricity to individual homes would be possible. Whether the advantages of villagisation and accompanying electrification to the rural population outweigh any long term disadvantages is still open to discussion.

In some nations, the presence of entrepreneurs in the countryside has permitted the development of small and unsophisticated hydropower plants to provide power, often direct mechanical power, to a variety of enterprises, sometimes replacing expensive diesel fuel which is difficult to transport to the rural areas. Such small enterprises include hulling rice, milling grain, expelling oil from seed, sawmilling, cash-crop drying and small workshops which provide employment for a few of the local people.

A number of missions throughout Burundi have been involved in setting up diesel-powered mills on their premises as well as assisting private individuals. These mills are primarily for the milling of manioc and millet and, to a lesser extent, wheat and corn. This is one end-use which can be served very easily with hydropower and at very low cost and complexity. A more viable option for "rural electrification" might be to assist small entrepreneurs, including those presently using diesel, to install small water-powered mills. Costs of these mills could easily be covered by the revenues generated by the milling and excess power could be used for battery charging at a very nominal cost. Batteries would be owned by private individuals who would use them to power inexpensive solid-state fluorescent units in their homes. Where flashlights are used, these batteries could also be charged at these mills. A simple car alternator could be used for this purpose. No governing would be required for these plants.

In Nepal, for example, there was a need to dry ginger, an important cash crop in the hill areas, during the wet season. As a result, a mechanically-driven forced-air heater was developed locally which could operate whenever the power plant was not being used for some other purpose. It provided a simple base load which permitted maximum productive use to be made of the power available day and night.

At Gatundu, a short drive north of Nairobi, excess energy from traditional underpower grain mill is used to drive an automobile alternator to charge batteries. One battery was then carried up the hill where it powers a television set in a community viewing area. Such batteries could also provide lighting for homes too far to be economically electrified by a conventional distribution system.

In the planning stages, it must be kept in mind that, though one objective is to exploit an appropriate source of energy to facilitate the development of the country in general and the rural areas in particular, it is necessary that income-generation be an integral part of the development of a rural electrification program. Having lighting in a rural home may well be pleasant but is of little real benefit to its occupants. Electrical power must be used to generate income, both to permit the rural population to develop economically as well as to permit them to pay for this service. The government cannot afford to completely subsidize electricity provided to rural areas, and it cannot assume that international funding institutions will continue doing so. Since using a hydropower plant to full capacity is no more costly than using only a small portion of its installed capacity, income-generating end-uses must be found to make use of all the power plant's capacity. Tasks presently requiring human or other forms of energy but which could profitably utilize the power from small-hydropower plants must be surveyed and new uses attempted.

Implementing a micro-hydro program

One should not be under the illusion that implementing a micro-hydro program is merely an extension of an existing small-hydro program. Its emphasis is not primarily on replacing fuel imports but rather with providing energy to facilitate rural development. It is often not concerned with furnishing electricity to those who already have some use for the energy but rather with furnishing mechanical and/or electrical energy to those who at present have no energy but potentially could put it to good use. It is often not implemented near urban centers or along the principal roads but rather in more remote, less accessible areas. It cannot rely on expensive and sophisticated imported equipment but rather must assemble and coordinate indigenous expertise to design and fabricate its own. It cannot afford contractors to construct the hydropower schemes and a central office to manage, operate, and maintain these schemes but must rather involve the local population to the maximum extent possible. It must rather seek out, develop, and disseminate new income-generating end-uses to permit an economically viable program in addition to providing power for lighting and other common end-uses. There are other unique aspects of a micro-hydro program. The above list is only illustrative but should give at least an indication that a new approach will be required to implement a micro-hydro program.

For a micro-hydropower program to succeed, it must be managed by an institution which can commit the necessary time and range of expertise, an institution that is dedicated to the task of rural development and has access to the numerous disciplines which are needed. The generation and transmission of electrical power is just one small component of such a program. It must be staffed by individuals who are committed to the task, willing to spend time in the field, and sensitive to the needs and realities in the rural areas. Developing a micro-hydropower program means developing essentially a new program and this task will require considerable effort. A micro-hydropower program should be initiated only if this level of effort and commitment can be guaranteed.

If there is sufficient commitment to the idea of a micro-hydropower program after its implications in terms of inputs are realized, the first step would be to determine the feasibility of such a program. Adaptive research and development into turbine design is straightforward and should probably not be undertaken in the preliminary stages of a small-hydropower program since this is likely to drain resources which should be directed toward the implementation of the initial schemes. First, there is a need to determine the types and extent of economically viable end uses in the rural areas which require some form of energy. The distribution and extent of hydropower resources (flow and head) must be

surveyed to determine whether these are accessible to potential end-users of power. It will also be necessary to study whether appropriate institutions (missions, cooperatives, farms, etc.) or individuals (mill-owners, shop-keepers, carpenters, etc.) exist with the necessary technical and managerial expertise. Only if sufficient indications exist that a micro-hydropower program can be viable should such a program be initiated.

ANNEX A: Excerpts from Presidential Decree No. 100/18 of February 2, 1979, of relevance to rural electrification

Art. 1. Establishes the Département de l'Hydraulique et de l'Electrification Rurales within the Ministry of Rural Development

Art. 2. Objectives:

- o ...(all concerned with water)
- o rural electrification

Art. 6. The Director of the Départment is responsible, inter alia, for—

- o ....; and
- o negotiating with financial organisms

Art 9. The Director of the Département is assisted by a Consultative Committee chaired by the Directeur Général du Développement Rural and including—

- o a representative of the Ministry which has Finance among its reponsibilities, etc,
- o a representative of the Ministry which has Public Works among its responsibilities,
- o a representative of the Ministry of the Interior,
- o a representative of the Ministry which has Industry and Artisanal Industry among its responsibilities,
- o a representative of the Ministry of Public Health,
- o the Director of Rural Settlement, and
- o the Director of Cooperatives.

ANNEX B: Mandate of the Direction Générale de l'Energie (Excerpt from Presidential Decree No. 100/19 of February 6, 1980)

Art. 2 The Direction Générale de l'Energie consists of two Directions: the Direction des Recherches et des Statistiques and the Direction des Projects.

1. The Direction des Recherches et des Statistiques consists of two Sous-Directions, to wit:

   a) the Sous-Direction des Statistiques, which is in charge of—

      - evaluating the energy needs of the various sectors of the economy and of national life; and,
      - compiling statistics on (energy) consumption, past and foreseeable, with a view to defining a national energy policy.

   b) the Sous-Direction des Recherches, which is assigned the tasks of—

      - inventorying the energy potential of the country;
      - keeping track of world research on new energy sources; and,
      - keeping track of research conducted in the fields of geothermal and hydrocarbon energy, notably as conducted by the Direction de la Géologie.

2. The Direction des projects consists of two Sous-Directions, to wit:

   a) the Sous-Direction des Etudes, which is assigned the tasks of—

      - elaborating the terms of reference of contracts for studies or implementation (of projects);
      - supervising studies until the preparation of a dossier for calls for bids;
      - examining the reports of consulting engineers, with a view to letting contracts; and,
      - keeping track of programs and actions of regional institutions or world organizations of which Burundi is a member

   b) the Sous-Direction du Contrôle, which is responsible for—

      - overseeing electrification and water-supply projects which have been carried out on behalf of the Government;
      - supervising and coordinating activities aimed at the utilization of energy resources; and,
      - overseeing the implementation of projects of regional interest, in which Burundi is an active or interested partner.

ANNEX C: Priority setting by DHER in the rural electrification sector (based on an interview with M. Augustin HAKIZA, Directeur, DHER, and M. Robert Gambart, Ing., Conseiller Technique, Nov. 11, 1982)

DHER does not use a quantitative priority-setting procedure based on weighted factors. Rather, it has an idea of what an ideal site should be and then determines how far or how little a particular site deviates from the ideal.

DHER's small-hydro program is still largely determined by the initiatives already taken by the missions (e.g., sites near missions, design work and financing provided by the missions, and willingness of missions to act as building contractors).

With new plants, DHER is guided by the following general guidelines:

- DHER is concerned essentially with the Nile drainage (i.e., the interior of the country) as the Zaire drainage is left to REGIDESO (larger power station and grids emanating from there);
- small-hydro plants must be located beyond foreseeable extension of REGIDESO's isolated grids (e.g., Gitega, Bururi), as determined from informal contacts with REGIDESO's planners; and
- relatively low unit cost (cost per kW installed).

The scope of DHER's program within any period is obviously determined by financial and manpower constraints. At the moment, this limit seems to be 5-10 projects over a five-year period.

An "ideal" first-priority site would have all the following attributes, in a rough order of importance:

1. near a "new village" under the villagisation scheme (political consideration);
2. provided that "new village" has (usually existing) large consumers such as hospitals, schools, agro-industries, artisanal industries, research stations or other government institutions;
3. the hydro site has a high power potential (i.e., close to the 250 kW limits imposed on DHER), and this potential can be developed easily (i.e., good access, sound geology) at low cost (few civil works);
4. the total present load is high, but the exploitable potential allows for another approximately 20 years of load growth;
5. other rural centers nearby can be connected with a low-voltage line;
6. hydro plant allows the elimination of diesel generators;
7. dynamic local leadership and initiative which have pressed for hydro development; and
8. site can supply a foreign-aid project (e.g., an agricultural research station) which may make it easier to secure external financing.

In the case of the five small-hydro plants proposed for 1983-87, the following considerations were important:

- Buhoro (180 kW): high potential, inexpensive site, new village plus mission, two additional centers (Makebuko and Muliza) can be served (within 10 km); diesels eliminated.
- Nyangwa (200 kW): high potential, inexpensive site, can serve Nyangwa, Mayana, Mahwa, and Gishubi; also Kiryama dairy plant and three Belgian-sponsored agricultural research centers (possibility of partial Belgian financing of hydro plant); diesels eliminated.
- Murago (60 kW): good, inexpensive site, good load (hospital, school, workshops, cooperative outlet); local dynamic initiative (Italian volunteers); diesels to be eliminated.
- Butezi (90 kW): medium-quality site 9 km from load center, but new hospital, school, mill businesses; dynamic leadership of local Italian mission; diesels to be eliminated.
- Kibuye (30-60 kW): small site, relatively expensive; mission, hospital, and school; requested by Ministry of Planning.

The following examples illustrate other aspects of small-hydro planning and the relationship between DHER and REGIDESO:

- At Buta (about 10 km SE of Bururi), a local hydro site was too poor to develop. DHER thus arranged for REGIDESO to run a line (6 km) from the Bururi grid. The cost of FBu 12 million (US$ 133,000) was borne by DHER. In return, Buta consumers receive "free" power. The Buta small-hydro plant would have cost DHER FBu 10 million to develop (capacity unknown).
- At the Mutoyi mission, the decision was taken (apparently by DGE-REGIDESO) not to develop a local 100 kW plant (i.e., theoretically falling under DHER's jurisdiction). Instead, a 15-km line was run from REGIDESO's Gitega (Mugera) plant. The area now served, although it comes under rural development policies, is now charged at the regular rate (FBu 7.6/kWh). REGIDESO apparently wants to develop a 2 MW plant in the Mutoyi area at a later date, primarily to serve the Gitega area. Thus, the transmission line has already been installed and is being amortized.
- At the Mugera mission, 10-12 km northeast of Gitega, REGIDESO has not assumed control of a small (ca. 60 kW) decentralized plant built by Pere Beuret, nor are there plans to connect this plant to the Gitega grid as sometimes reported. This small plant was temporarily shut down while REGIDESO's own larger (1.2 MW) Mugera plant was under construction. REGIDESO has now restored the diversion canal to the mission plant which remains under the mission's control.

ANNEX D: Hydropower plants under construction or operational*

Location	Head(m)	$P_{installed}$ (kW)	Notes
Mugera	17	1,200	situated on the Ruvyironza river, serves Gitega; financed by Germany who also supervised construction; two Ossberger, turbines presently installed with provision for one more
Mugere		8,000	four 2-MW units installed by the Chinese to provide power to their textile mill and Bujumbura; located south of the capital
Gikonge	27	800	situated on the Mubarazi river and serves Muramvya; uses two Ossberger turbines; financed by Germany; present peak load less than 10% of installed capacity
Muyinga	27	800	designed and financed by Germany; civil works constructed by Chinese; to use Ossberger turbines
Kirundo		240	financed by Germany
Giheta	5	30	situated on the Ruvyironza river and initially to serve mission; uses propeller turbine from Leroy-Somer; designed by Père Beuret; to accommodate three turbines if load warrants in future; slightly greater than half financed by FED, with turbo-generator package financed by France, remainder financed by Burundi (see Annex F for further details)
Bubanza	17	140	on the Mpanda river; 70% financed by FED and remainder by Burundi
Ryarusera	40	20	situated on the Kayogoro river; designed by Père Beuret; uses a Pelton turbine from Cavaloc (France); 70% financed by FED and remainder by Burundi
Kigwena	140	50	situated on the Nzibwe river; designed by Père Beuret; 70% financed by FED and remainder by Burundi

*This table is based on a survey performed by Bernard Crétinon, DHER, with additional information from other sources. Values for head and installed power are only approximate as different sources of information give differing values.

Buhiga	26	220	situated on the Ndurumu river; to serve Buhiga and Karusi; will use an Ossberger turbine (see Annex F for further details)
Nyabikere	20	110	situated on the Nyabizi river; financed by Burundi; to use an Ossberger turbine; to begin operation in early 1983 (see Annex F for further details)
Ruyigi	8	70	financed by Burundi; situated on the Sanzu river; designed by Père Beuret; uses an Ossberger turbine; to be operational end-1982 (see Annex F for further details)
Kiganda	16	40	situated on the Mucace river and being built by mission at Kiganda; financed by Fonds Blé et Farine
Mugera		50	situated on the Ruvyironza river and serves mission; installed in 1965 and designed by Père Beuret; uses a Francis turbine (see Annex F for further details)
Masango		25	designed by Père Beuret and installed in 1978 to serve mission of the Soeurs d'Ingenbohl; uses an Ossberger turbine
Kiremba	9	70	designed by Père Beuret; serves mission and hospital; uses an Ossberger turbine; uses unlined earth power canal
Mutumba		25	situated on the Kirasa river; designed by Père Beuret and serves mission; uses a turbine from Bouvier (see Annex F for further details)
Burasira	3	20	serves the Grand Séminaire; uses an Ossberger turbine
Murore		10	uses a Pelton turbine
Chibitoke		70	installed about 1970; uses a Francis turbine
Kibumbu		60	serves mission, sanatorium, and school; uses a crossflow turbine; has two back-up diesels (20 and 25 kW)
Kibimba	21	15	situated at falls on the Kaniga river; uses an oversized Pelton driving an 80 kW generator (see Annex F for further details)
Teza		360	installed in 1971 to provide power to a tea factory; uses a Francis turbine from Maier; available capacity only 200 kW
Gisozi		15	broken down since 1977 but repairable

Kayero			not used at present
Kwisumo			located at a Friends' mission; currently generator rotor being repaired
Musongati	40	20	uses a Pelton turbine from Cavaloc; generating only a couple kilowatts a few hours per day because of small streamflow (see Annex F for further details)

ANNEX E: Some proposed hydropower sites

Location	Head(m)	$P_{installed}$ (kW)	Notes
Buhoro	15	180	situated on the Nyakijanda river; located 2.5 km from mission at Buhoro, will also electrify Muliza and Makebuko, both greater than 10 km away; est. cost: FBu 80 million* (including transmission)
Nyangwa	16	200	situated on the Waga river and located 3 km from Nyangwa, to also electrify Matana, Mahwa, and Gishubi; site selected by the government: est. cost: FBu 120 million (including transmission)
Murago	90	60	1.5 km from Murago situated on the Ngonya river; to electrify hospital, workshops, school, commercial center and other existing infrastructure: est. cost: FBu 20 million (including transmission)
Butezi	8	90	9 km from mission at Butezi on the Sanzu river; to electrify mission, hospital, school, cooperatives, and workshops; est. cost: FBu 40 million (including transmission)
Kibuye			situated on the Ruvyironza river; to electrify hospital; requested by the Ministry of the Plan; either one of several sites (30-60 kW) to be developed
Bigugu	40	2,400	one of eight sites studied by GTZ (1981) and eventually rejected; it was to serve Ngozi, Kayanza, Rwegura, and Remera; plant with 38-meter high earthfill dam on Ruvubu river with a 4 km^2 reservoir
Rutana	180	2,400	one of eight sites studied by GTZ (1981); it was to serve Rutana and Mosso; plant with 30-meter high earthfill dam with reservoir area of 1 km^2 on the Muyovozi river

* FBu 89 = US$ 1.00

Rwegura	490	18,000	to serve an area south to Bujumbura and east to Ngozi; planned to operate by 1987; would also provide water regulation that could benefit irrigation and future power projects downstream; est. cost is considerably high (about FBu 17/kWh). Scheduled to be constructed 1983-86.
Nyemanga	230	2,000	situated on the Siguvyaye river, to serve Buriri

ANNEX F: Hydropower schemes visited—brief descriptions and comments

1. Ruyigi

This DHER site is located northwest of Ruyigi on the Sanzu river and will provide power to the mission, school, a military camp, and small commercial establishments. The civil works have all been completed and the plant is being wired. An 800-meter power canal is to convey about 1 m^3/s to the powerhouse which is located below ground level in an area excavated in rock. A 10 kV line brings power about 2 km to town. This scheme, designed by Père Beuret, was funded by the government and built under contract by the local Mission. It should be on-line by the end of 1982.

Given the gradual gradient of the Sanzu river, there is no cost-effective way of avoiding the relatively long power canal to convey the water to the plant. The powerhouse could have been located essentially at ground level, thereby reducing the volume and cost of excavation in rock but increasing the length and cost of the steel penstock. It was not possible to determine the rationale for the actual design.

(Contact: Robert Gambart and Bernard Crétinon, DHER)

2. Musongati

At present, a 2 meter high concrete masonry dam captures a small stream and provides an estimated 150 m^3 of storage capacity. An oversized Pelton turbine is driven to generate several kilowatts for part of each day. The governor (Dumont) was disconnected since it consumed a significant portion of the power available. An 11 kV line transmits power about 1-2 kilometers to the mission and health center. In order to increase generating capacity, the powerhouse is being resited and is presently under construction under a head of 60 meters and an appropriately sized Pelton turbogenerating unit has been ordered from Cavaloc. The dam is to be heightened to increase the storage capacity about three-fold. This plant was designed with the assistance of Père Beuret and M. Zorzi.

Given the topography of the area, placing the new powerhouse further downstream will permit optimal development of the site. And with the small catchment area available, increasing the dam height will provide increased generating capacity for at least part of the year. How significant this will be depends on a more precise knowledge of the actual flow characteristics of the stream. A lack of this knowledge already resulted in incorrect turbine specifications for the unit presently installed. To ensure the integrity of the dam, it will be necessary to verify that the higher dam is of the proper design and that a suitable foundation exists. The use of polyvinylchloride (PVC) pipe for the penstock is envisioned since it is often less costly and much lighter and easier to handle than steel. However, PVC degrades when exposed to ultraviolet light from the sun and it is recommended that the pipe be either buried (which would be difficult at Musongati) or at least painted.

(Contact: Père Joseph, Musongati)

3. Kibimba

This plant, located at a waterfall, belongs to the Mission Evangélique des Amis and serves the mission and its school, clinic, workshops, and housing for its staff. A very short power canal conveys water into a nearly vertical penstock at one side of the falls to the powerhouse at the base of the falls. It presently generates only about 15 kW which is transmitted four kilometers to the mission on a 2.4 kV line. The governor caused problems and was disconnected. The turbine is now governed by switching ballast loads (water heaters) on and off in one of the mission houses. Stones thrown on the corrugated galvanized roofing by children pierced it and rainwater caused a short in the generator in 1972. Until 1977, the plant was therefore not operational and diesel generators were used to supply power to the mission. One of the troublesome problems which remain has to do with lighting arrestors but the absence of the

man in charge prevented getting further details.

With a relatively low head of 21 meters and a power potential on the order of 100 kW, the Pelton turbine is not the proper turbine type for the site. Either a Turgo or crossflow turbine would have been more appropriate. The reason for selecting the present turbine is unknown.

The use of manual governing of the turbine represents the least sophisticated and least costly form of governing. It does, of course, require a responsible individual to be on hand. Technical qualifications are not at all required of this individual. It was interesting to note further that a whole range of appliances were being used at the mission, from fluorescent lamps to blenders, washing machines, hi-fi's, and microwave ovens and all function properly. The nominal frequency is 60 Hz (an American standard used at the mission) but decreased to 50 Hz in the evening hours when the load was high. Since power was limited, it was policy that no large power-consuming appliances could be used between 6 pm and the time that lights went out for the 450 boarders at the school.

(Contact: Mrs. Connie Young, Kibima)

4. Giheta

This scheme is located in parallel to a set of rapids along the Ruvyironza river which drops about 5 meters over a distance of a couple hundred meters. At the end of the power canal will be located a 30 kW turbogenerating unit from Leroy-Somer which is already on site. This is a package which includes a propeller turbine (with manually adjustable blade angles), an induction generator with excitation system for off-grid application, and a load controller using radiative heaters as ballast loads. The civil works are designed so that three such units can be accommodated should the need for power in the future encourage this. Initially, the power will primarily be transmitted at 10 kV a distance of about 4 km to the mission. Local eucalyptus trees are being cut and surface treated. Completion of a diversion structure was delayed and the unexpected arrival of heavy rains and increased flow in the river cause the bank on the far end to erode, causing the length of the eventual structure to be approximately twice that originally planned. Because of recent heavy rains, two coffer dams were breached and the remaining few meters of the diversion structure may now not be completed until the dry season in mid-1983.

An induction generator package will be used at this site because an induction generator is (1) less expensive than a synchronous generator usually used in decentralized applications, (2) can better accommodate overspeed conditions should the load be inadvertently lost, and (3) can more easily be eventually interconnected to the REGIDESO grid from Gitega, 10-15 km to the east. The more conventional approach is to use a synchronous generator with governor. Though the approach used at Giheta has essentially no moving parts and from that point of view is more appropriate, it is a state-of-the-art development and has not had a long history. Its ruggedness and reliability are yet to be determined.

(Contact: Bernard Crétinon, DHER, and Père Franz Pristle, Giheta)

5. Nyabikere

This scheme will harness a portion of the water leaving a flat, swampy plain before it cascades over rapids. It is diverted into a power canal a couple of hundred meters long before dropping 20 meters through the penstock and powerhouse back to the original streambed. The entire stream has been temporarily diverted to permit construction of the dam. This dam will have a wide crest to permit motor vehicles to ford the river. The power is to be transmitted 4-6 kilometers at 10 kV to serve the village center and Zamandore Mission.

The need to develop a standard design philosophy and appropriate designs is again apparent at this site. The dam which is to serve both as a diversion structure and a ford, though impressive in size and quality of

workmanship, is larger than need be, resulting in unnecessary added cost, labor requirement, and time for construction. The dam could have been replaced by a concrete-masonry structure only sufficiently high to fill in the rock outcropping at the top of the rapids. Even as it stands, slightly over a meter high and eventually about five meters wide, there is no need for either the sloping faces on both sides nor the anchoring of the dam to the rock foundation. The mass of the structure, the bond between the concrete and rock foundation, and the mechanical coupling between the dam structure and the rugged rock outcropping are more than necessary to support the forces against the dam presented by any flood waters.

(Contact: Bernard Crétinon, DHER)

6. Mutumba

This plant located just off the main road south from Bujumbura provides up to about 30 kW to the mission station. It was designed by Père Beuret and has been operational about two years. At the site, a portion of the streamflow is drawn off to one side of the stream into a settling area/power canal/forebay about 20 meters long before dropping 8 meters through a horizontal Francis turbine. Second-hand equipment has been used in the powerhouse. A transmission line transmits power 1-2 km up to the mission.

As originally planned, the power canal was to extend somewhat closer to the powerhouse to minimize the length of penstock required. However, it was built on a slope with an inadequate foundation and collapsed. The present design has posed no problems since it began operation. Trash is removed daily and the settling areas are cleaned out only a few times a year.

(Contact: Père Othmar Landolt, Paroisse Mutumba)

7. Buhiga

Construction of this scheme near the Mission of the Eglise Episcopale du Burundi is under the direction of Geoff Bishop, an Australian mining engineer who has worked at Buhiga for eight years. Its design was prepared with some outside assistance, with ideas gained by visiting sites and talking to individuals in-country. A concrete masonry gravity dam diverts the water from the upper reaches of the Ndurumu River into the intake and settling area and on into a 440-meter power canal. The dam and power canal are each about half complete, the steel penstock pipe is on site, an Ossberger turbogenerator package should shortly be making its way inland from the coast, and eucalyptus transmission poles are being prepared and installed.* The total cost of FBu 70 million is borne entirely by the mission which is also in charge of construction.

A small plant with an installed capacity of 60 kW to serve the mission area 1-2 km away with a 10 kW line was initially envisioned. However, permission to build the plant was granted by the government only on the conditions (1) that its capacity be increased to make optimum use of the streamflow, and therefore potential power, available and (2) that power be transmitted down the road about 8 km to the center at Karusi, which is the administrative center for one of the newly formed provinces. Accordingly, the plant's design capacity was increased to 220 kW based on initial streamflow estimates.

After commencing with the construction of the dam, the flow was found to be about twice that originally estimated for most of the year. The government subsequently required that provision be made for the eventual installation of a second turbine in the powerhouse to double the plant's capacity.

Initially, only lighting and some small workshop equipment will be the load. It is hoped that the institutions at Buhiga (trade school, Ecole Normale, and the hospital) will be able to replace wood for cooking with

*Standard REGIDESO electrical components are being used to facilitate future maintenance and repair.

electricity. This should consume a peak load of about 60 kW. There will probably be a large excess of power for some time into the future. The primary concern at present is who will be responsible for the operation and maintenance of the plant after it goes on-line. This is a question which DHER will have to address for all its plants. At Buhiga, they will not be able to fall back on the mission to run the plant as Geoff Bishop plans on leaving the mission upon completion of the work and no one is to replace him.

(Contact: Geoff Bishop and Phillip Alston, Buhiga)

8. Mugera

This 50-kW plant to serve a mission several kilometers away was also designed by Père Beuret. It is fed by waters diverted by a diversion dam across the Ruvyironza River into a power canal a couple hundred meters long. More recently, the intake was modified by REGIDESO and then used to also provide water to its own Mugera plant which presently generates 800 kW for the area of Gitega 10 km to the south. In its present configuration, a large canal about 1 km long from the intake serves to convey water for the REGIDESO plant and a short spur at the beginning of this main canal continues to provide water to the 50 kW plant.

ANNEX G: Electric-arc process for the production of nitrogen fertilizer

This idea has gained fairly widespread dissemination as a result of a number of small-hydropower workshops held under various auspices around the world. Though it has an appeal because it is essentially a simple process, it is small-scale, produces a commodity in substantial demand around the world, and, when utilized in conjunction with small decentralized hydropower plants, uses energy which would otherwise be wasted. This process is not yet ready for widespread dissemination and use.

Basically, the electric-arc reactor is an iron pipe with a high-voltage electrode along its axis. An arc is struck between the electrode and the pipe and nitrogen in the air which is forced down the pipe dissociates to form nitrogen oxides which are then dissolved in water. When the resulting acid solution is passed through a column containing crushed limestone, a calcium nitrate fertilizer in solution is produced. It can be used in liquid form or dried.

At present, the process has an efficiency of 1-2%. Though this low efficiency might of little importance when the energy to drive the process is free, as would be the case when used as a load-leveling option for SDH plants, a significant capital investment is required for the equipment. At present, the cost of a 3 kW unit is about $2,000, the most costly item being the transformer. Standard distribution transformers were used but the output could not be properly controlled. Special, more expensive, transformers with saturable cores would probably be required.

Before this technology can find more widespread use, it will be necessary to evaluate progress to date and to make explicit the cost and complexity of the process all the way through to the production of a fertilizer in dry form, the level of expertise to operate and to maintain such a plant, and technical obstacles, if any, which are yet to be overcome.

ANNEX H: Persons contacted

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