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DECENTRALIZED HYDROPOWER IN AID'S DEVELOPMENT ASSISTANCE PROGRAM

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In November 1984 the Administrator of the U.S. Agency for International Development (AID) ordered a reassessment of all renewable energy technologies that were the subject of agency programs. This reassessment had three objectives:

- "To assess priority applications of renewable energy technologies with emphasis on productive uses in agriculture and rural industry;"
- "To recommend development and application of those renewable systems which, when compared with alternatives, are the least-cost, site-specific solutions to supply energy needs;" and
- "To suggest means of developing local private-sector capability to market, manufacture, and maintain the most promising renewable energy systems and to involve the private sector at an early stage in AID projects."

This paper by AID's Bureau of Science and Technology, Office of Energy (S&T/EY) responds to the Administrator's request by reassessing one of the most promising renewable energy options for developing countries, decentralized hydropower.

In 1983, decentralized hydropower was responsible for the generation of nearly 10,000 MW of power at remote sites around the world. By 1991 it could generate three times that amount of power. A sample of AID-assisted countries for which data are available shows that decentralized hydropower potential represents about 10 percent of total hydropower potential, and in some countries is equal to total current power demand. Thus, this resource can make a major contribution in meeting the priority energy needs of many countries, particularly in agriculture and rural development.

Where decentralized hydropower is technically feasible it offers many advantages over conventional small power generating alternatives such as diesel systems:

- The technology is well developed, widely available, and easily understood;
- It exploits the high annual rainfall and rugged topography found in a number of AID-assisted countries;

- It is economically competitive with both diesel power and with extension of the existing power grid;
- It can be integrated with other water-resource development projects such as irrigation to provide a power source at a comparatively low incremental cost;
- It reduces the demand on foreign exchange reserves by reducing oil imports for power generation and by using a relatively large component of local labor, equipment, and services; and
- It reduces expensive overbuilding of power generation capacity because it is added in relatively small increments and has shorter construction lead times.

Despite the advantages of decentralized hydropower countries face serious obstacles to its full utilization:

- The hydrological data required to assess a site and optimize its economic performance are not widely available in developing countries;
- Initial site design and capital costs may be unnecessarily high because of reliance on foreign experts and equipment, inappropriate designs, and unrealistic requirements for detailed site assessments;
- Host government energy policies may discriminate against small power producers;
- The host country government and private sector organizations may not have the technical and managerial capability to properly design, construct and operate the facility; and
- Demand for the power near the site may not be sufficient for the project to be cost-effective.

To ensure the fullest realization of decentralized hydropower's potential, S&T/EY has developed a twofold strategy. First, it will leverage its limited funding by serving as a catalyst to decentralized hydropower development. It will do this by conducting preliminary reconnaissance and prefeasibility analyses to identify potential sites for cost-effective applications and then "brokering" these sites by bringing together potential developers such as U.S. and local private sector institutions with potential financiers such as local and international lending institutions. These developers and institutions will then assume the primary responsibility for

detailed planning, financing, constructing, and operating the sites, with only minor additional assistance from AID.

Second, S&T/EY will include decentralized hydropower as a key energy option in the Small Utility-Scale Power Systems, Industrial and Village-Scale Power Systems, Energy for Irrigation Pumping, and Energy for Agroprocessing and Other Rural Industries, and Irrigation and Energy Planning in River Basin Development. Competing options will include both conventional power sources such as diesels, grid extension, and industrial cogeneration and other renewable power sources such as wind, photovoltaics, and biomass. S&T/EY will thus insure that decentralized hydropower will be evaluated wherever it can meet a need for power, and that those applications where it is the best option will be identified.

To implement this strategy, S&T/EY will focus on the following accomplishments for FY86:

- Identify two AID-assisted countries that appear to have significant decentralized hydropower potential;
- Conduct reconnaissance and prefeasibility studies using U.S. and, if available, host-country experts in these two target countries;
- Prepare a portfolio of "bankable" projects suitable for implementation based on the above studies;
- Identify government impediments in these countries to cost-effective decentralized hydropower development (such as fuel subsidies or electric power generation monopolies) and work with host country energy planners to reduce or eliminate these;
- Broker development of attractive sites by bringing together potential site developers with potential lenders; and
- Provide training when necessary to host-country personnel in areas such as: estimating project performance from hydrologic data; preparing engineering designs; estimating capital and operating costs; assessing local power markets and revenues; preparing financial plans for lenders; carrying out project construction; and providing project operation and maintenance.

There are no budgeted funds for decentralized hydropower efforts in FY86. However, as of November 1, 1985 approximately $350,000 remains from previous years to fund general support services provided under a Cooperative Agreement (AID/DSAN-CA-0226) by the National Rural Electric Cooperative Association (NRECA). To use these funds most effectively, S&T/EY will focus its efforts on two highly promising

countries. One of these countries, Madagascar, has already been selected for reconaissance and prefeasibility studies; one more will be selected by February 28, 1986.

The remainder of this paper is organized as follows: Chapter II discusses the rationale for AIDs interest in decentralized hydropower, the state-of-the-art of the technology, and the lessons learned from past experience on how such a technology can best be implemented. Chapter III describes the strategy and implementation plan that AID will use to maximize its limited resources. Supporting materials are provided in Annexes A, B, C and D.

CHAPTER 2

PROGRAM RATIONALE

INTRODUCTION

This section provides a brief background for understanding the issues affecting decentralized hydropower in AID-assisted countries and discusses what is needed to insure its cost-effective implementation. First, the energy problems facing developing countries are reviewed. Next, the potential for meeting these needs through decentralized hydropower is discussed. Then, the current status of the decentralized hydropower technology is summarized. Finally, the lessons learned about implementing this technology in developing countries are described.

THE ENERGY PROBLEMS FACING DEVELOPING COUNTRIES

AID's Bureau for Science & Technology, Office of Energy (S&T/EY) recently issued a policy paper on energy [1] indicating that economic growth and energy use (particularly of oil and electricity) in AID-assisted countries are closely correlated. In fact meeting AID's target goal of a 2 percent annual growth in real per capita income will require an average annual energy use growth rate of at least 7 percent. Many of these countries will have difficulty meeting this economic growth target because they will have difficulty paying for the energy while maintaining productive investments in other sectors of their economies. For example, half of all developing countries rely on imported oil for over 75 percent of their commercial energy needs [2], a reliance that is not likely to decrease much in the forseeable future. Oil imports alone absorb one-quarter to one-half of export earnings, reducing the foreign exchange available for productive investments.

At present, developing countries are spending over 4 percent of their GNPs on energy resource development, representing 25 percent to 35 percent of their total annual capital investment. This investment is much greater than the 2 percent to 3 percent typically spent in the late 1970s, and is likely to continue increasing. The World Bank estimates that development of the energy sector in these countries will require annual investments of $130 billion during this decade, over half of which will be foreign exchange [3]. S&T/EY estimates that electric power generation investments alone in AID-assisted countries will require $177 billion to $266 billion over the next 15 years [4].

Ample supplies of energy are particularly critical in agriculture, since most AID-assisted countries rely on irrigation to increase agricultural output. Pakistan uses 23 percent of its power generation for irrigation. India's agricultural electric load which is used primarily for pumping increased from 118 MW in the early 1950s to almost 13,000 MW in the late 1970s. Future expansion in pumping will need to rely on electricity and diesel power, since alternatives such as gravity pumping have been used as much as is practical.

To maintain its economic growth and meet the resulting growing demand for energy, a developing country must rely on a twofold strategy. First, it must encourage the efficient use of energy by the major consuming sectors. Second, it must utilize domestic energy resources whenever they are cost-effective. S&T/EY is assisting developing countries implement both parts of this strategy [5].

CURRENT STATUS OF DECENTRALIZED HYDROPOWER

Decentralized hydropower is among the most promising of the renewable energy resources in many developing countries. It includes relatively small hydropower sites, typically less than 15 MW (representing an investment of typically less than $30 million), which can be either isolated or part of an electricity grid. These sites can provide either electrical or mechanical power and in many cases primarily serve a local demand such as power for an industrial plant or irrigation. Often, they are financed, owned and operated by local users rather than a large central electric utility. In contrast, centralized hydropower sites are usually quite large (up to thousands of MW), can cost billions of dollars and are usually owned by the government, a parastatal or a large electric utility.

Detailed surveys of decentralized hydropower potential have been carried out in only a few countries and data are generally difficult to obtain and compare on a consistent basis (e.g. the capacity definitions for decentralized hydropower vary significantly). The available data for 25 AID-assisted countries are summarized in Table .. For these countries, the data suggest that decentralized hydropower is a large resource, averaging about 10 percent of total hydropower capacity in most countries and at least equaling the total current power demand in a number of them.

According to a study of the future worldwide demand for a variety of different generating options [6], decentralized hydropower is expected to serve primarily agriculture and village electrification. The study estimates that in isolated, stand-alone systems in 1983, decentralized hydropower generation totaled nearly 10,000 MW worldwide, compared with 580 MW for diesel, 11 MW for wind generation, and negligible

Table 1. Decentralized Hydropower Potential of 25 AID-Assisted Countries

Region/Country	Estimated total hydropower potential (MW)	Decentralized hydropower potential (MW)	Total installed capacity from all sources (MW)
West Africa			
Guinea	5,000	560	151
Liberia	2,000	150	322
Sierra Leone	1,300	100	106
Togo	270	30	152
East Africa			
Burundi	800	460	26
Madagascar	7,800	270	250
Rwanda	600	30	37
South Asia			
India	100,000	10,000	42,374
Nepal	18,250	800	150
Pakistan	19,600	300	5,570
Sri Lanka	2,500	200	879
East Asia and the Pacific			
Indonesia	32,000	1,000	7,390
Papua New Guinea	29,000	4,000	427
Philippines	10,000	4,000	7,774
Thailand	20,200	1,066	7,632
Latin America and the Caribbean			
Bolivia	18,000	500	618
Costa Rica	9,100	2,700	818
Dominica	18	18	8
Dominican Republic	1,900	50	1,365
Ecuador	22,733	1,000	1,799
Guatemala	5,426	1,000	952
Haiti	152	152	173
Honduras	2,800	500	608
Jamaica	100	100	760
Peru	60,000	12,000	3,578
TOTAL	369,549	40,920	83,919

Sources for Table 1:

Estimated Total Hydropower Capacity and Total Installed Capacity are from A Survey of the Future of Hydroelectric Capacity in 100 Developing Countries, Energy Department Paper No. 17, The World Bank, August, 1984

Decentralized Hydropower Potential estimates are from the following sources:

Guinea—Evaluation de Ressources en Petits Amenagements Hydroelectriques en R.P. de Guinee, Rapport de Mission en Guinee, December 7-13, 1981, pp. 9-15.

Liberia—Decentralized Hydropower Program staff estimate.

Sierra Leone—Kamara DLB. Case Study: Establishing a Programme of Micro Hydro Electric Power Development for Rural Electrification in Sierra Leone. United Nations Development Program (UNDO), August 1, 1979.

Togo—Associates in Rural Development, Inc. Overview of the Togo Energy Situation, report prepared for the U.S. Agency for International Development, 1981, pp. 2-32.

Burundi—Action Program for Future Development of the Kagera Basin Power System with a Summary of Supporting Studies in Hydropower Potential, report of the UNDP Kagera Mission, November 1980.

Madagascar—'Possibilites Hydroelectriques,' map developed by the Ministere de l'Economie et du Commerce, October 31, 1978.

Rwanda—Action Program for Future Development of the Kagera Basin Power System with a Summary of Supporting Studies in Hydropower Potential, report of the UNDP Kagera Mission, November 1980.

India—Deodas T. 'Micro-Hydel Generation in India.' UNIDO ID/WG 329/6, October-November, 1980. Also see Seminar on Small Hydro Stations: Central Board of Irrigation and Power, January 1983. Estimates include 3000 MW of micro-hydropower (up to 2000 kW), of which 3000 MW are irrigation and water-supply canal drops; and mini-hydropower (up to 15,000 kW), 15,000 MW.

Nepal—Decentralized Hydropower Program staff estimate.

Pakistan—Decentralized Hydropower Program staff estimate.

Sri Lanka—Decentralized Hydropower Program staff estimate.

Indonesia—Notodipuro H. 'Centralized vs. Decentralized System of Project Planning and Implementation of Mini Hydro Power: The Indonesian Case,' paper presented at UNIDO workshop, Kuala Lumpur, Malaysia.

PNG—Decentralized Hydropower Program staff estimate.

Philippines—Santos CA. 'The Philippine Mini-Hydro Program.' February 1982.

Thailand—see ref. 4 above.

Bolivia—Decentralized Hydropower Program staff estimate.

Costa Rica—Decentralized Hydropower Program staff estimate.

Dominica—Figure based on assumption that all hydropower in small island countries falls into the small-hydropower capacity range.

Dominican Republic—Decentralized Hydropower Program staff estimate.

Ecuador—Evaluacion de Sitios Apropriados para Instalar Pequenas Centrales Hidroelectricas en el Ecuador, Informe de la Mision Enviada al Ecuador, November 14-30, 1981, Departamento de Cooperacion Tecnica para el Desarrollo, Naciones Unidas.

Guatemala—Decentralized Hydropower Program staff estimate.

Haiti—Figure based on assumption that all hydropower in small island countries falls into the small-hydropower capacity range.

Honduras—Decentralized Hydropower Program staff estimate.

Jamaica—Figure based on assumption that all hydropower in small island countries falls into the small-hydropower capacity range.

Peru—Decentralized Hydropower Program staff estimate.

amounts for other options such as photovoltaics. It predicts decentralized hydropower generation in isolated, stand-alone systems will climb to 29,000 MW by 1991.

Decentralized hydropower can be broken down into micro- and mini-hydropower [7]. Micro-hydropower sites are quite small, generally less than 100 kW. These sites can provide either electrical or mechanical power to meet the requirements of small discrete loads such as agro-processing and milling machines. In many parts of the world, the technical expertise necessary to successfully implement micro-hydropower projects -- water management, design and construction of rudimentary yet effective civil works, plant operation and management -- is locally available because of experience with traditional mills and irrigation systems. Micro-hydropower projects generally use simple, inexpensive equipment that often can be fabricated in-country. Entrepreneurs in several developing countries including Nepal, Pakistan and India have already begun manufacturing turbines, generators, load controllers, pipe and end-use equipment locally. They can provide a "turnkey package" service to rural customers to meet specific end-use power demands such as agricultural pumping or grain milling. Micro-hydropower manufacturing enterprises are beginning to emerge in Africa and Latin America as well.

Micro-hydropower is especially attractive as a low-cost energy option when direct shaft power is needed to drive oil expellers, sawmills, cane crushers, and flour mills. It can also be used to drive heat generators that heat air to several hundred degrees centigrade through viscous heating. The hot air is used for such purposes as dyeing, soap making, juice concentrate preparation, crop drying, and butterfat and cheese making, thus saving fuelwood and other scarce rural energy resources.

Mini-hydropower for this discussion includes sites having power outputs from roughly 100 kW to 15 MW. Typically these are sites often isolated from the main power grids which serve important rural energy markets such as groups of villages or small towns (possibly forming a small local electrical grid), larger cooperatives, farms, agro-processing plants and other rural industries. Mini-hydropower is also quite adaptable to labor-intensive civil designs, and in many developing nations the local metalworking skills and plant facilities are more than adequate to fabricate most of the components needed to equip the sites.

In addition to serving isolated loads, mini-hydropower sites often are appropriate for supplying a power grid. Several recent studies in developing countries on the impact of mini-hydropower plants on large transmission networks have shown that decentralized hydropower can reduce the net costs of power expansion and generation generation programs in three ways. First, they permit the energy generated by

decentralized hydropower plants when streamflow is adequate to be substituted for power generated by larger hydropower storage schemes, thereby increasing the effectiveness of storage in serving dry periods or peak demand periods. Second, they delay the need for large generating plants, thereby matching growth in generating capacity more closely with growth in demand and thus reducing the overall costs of power by. Finally, they reduce the foreign currency requirements for power system expansion by increasing the use of indigenous materials, equipment, skills, and labor.

RELATIVE COST-EFFECTIVENESS

Decentralized hydropower can be used to supply isolated loads or it can be part of an electric grid. The economic merits of decentralized hydropower versus those of the common alternatives for serving a remote load -- diesel generation and grid extension -- depend on parameters such as the water head and flow rates and the civil works required which vary considerably from site to site.

A study for the World Bank's Energy Department[3] estimated capital costs (in 1984 $) for "typical" decentralized hydropower systems. The turbine generator and control systems cost $300-600/kW, with the higher head systems (30m or more) at the lower end of that range. If the site is connected to an electric grid, power factor control and substation equipment will add about $100/kW. Remote control equipment, if required, adds another $20,000 per site. The greatest cost uncertainty is for the civil works, which are quite variable from site to site. If the system is retrofitted to an existing dam, these civil works can be as little as $100/kW. If extensive civil works are required, their costs can be $2,000/kW or more. Indirect costs such as site evaluation, engineering, finance and overhead are also quite variable, ranging from as little as 10 percent of the direct capital costs for large installations to over $6,000/kW for small installations[3].

Because of the large variability in costs among decentralized hydropower sites it is difficult to generalize about the site characteristics that are necessary for a cost-effective project. General "rules of thumb" suggested by the World Bank Energy Department are: a head of 3 to 50 meters; a water flow of 0.5 to 100 cubic meters per second; annual operation at full capacity of more than 2000 hours; and a size greater than 100kW. However such rules must be used very carefully since there is no guarantee a site meeting these requirements will be cost-effective, or that one not meeting these requirements will not be cost-effective.

A detailed economic comparison of diesel and hydropower for a range of typical capital and operating costs is provided in Annex B. This example shows that the diesel option is more cost-effective than decentralized hydropower when utilization of the plant's design capacity is low, e.g., when there is little demand for the power, when the demand is very peaky, or when the flow varies considerably from season to season or from year to year. However, when the capacity utilization is higher (typically 25 percent or more) hydropower can be the more economic option provided the energy is "firm", i.e., is available when needed. The hydropower option would be even more favorable if the numerous other indirect economic and social benefits, such as the use of indigenous resources and the conservation of foreign exchange, are explicitly included in the evaluation.

An important factor in the attractiveness of decentralized hydropower projects is the relatively large component of costs that can be provided locally, thus conserving foreign exchange. The foreign exchange cost component of five hydropower sites ranging from 40 kW to 292 MW are shown in Table 2 [illegible]. For conventionally designed projects, the local component of costs ranges from 75 percent for the largest installation to 51 percent for the smallest. The micro- and mini-hydropower sites usually have more of their costs supplied locally than do large hydropower sites. A study by NRECA for AID estimated that in Costa Rica, proper design could boost the local content of several projects under 1 MW in size to over 80 percent while reducing the sites' overall capital cost by 17 to 33 percent, compared with a more conventional design approach.

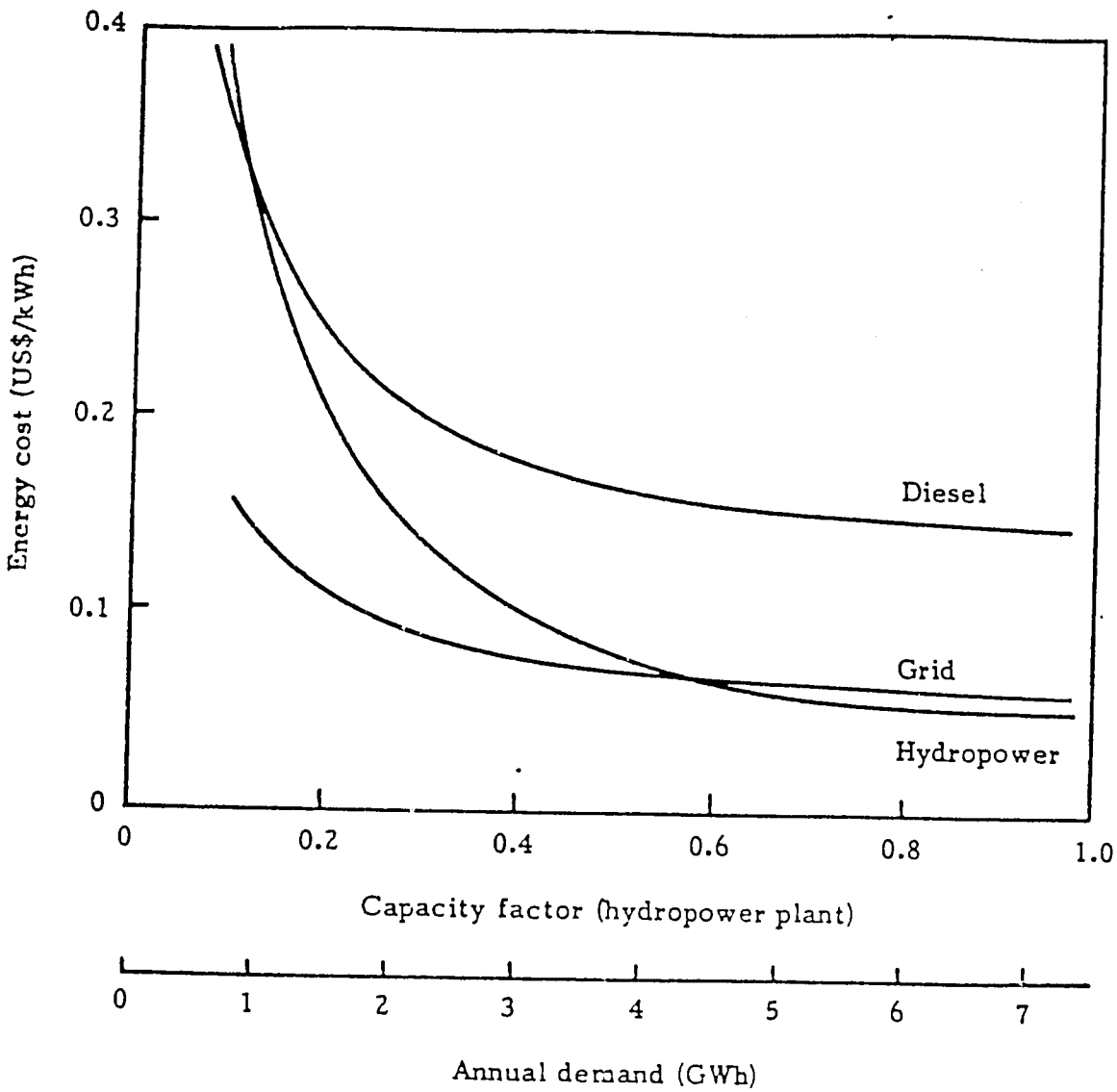
A direct comparison of the relative costs of grid extension, diesel generation, and decentralized hydropower generation was given in a study undertaken in Western Kenya by the United Nations Department of Technical Co-operation for Development as part of a series of studies of 47 developing countries [illegible]. The area obtained electric power for industrial and commercial use from small diesel generating sets that had a peak capacity of 380 kW. Under consideration was an 550 kW hydropower plant that would provide additional power for a population of 15,000 as well as for maize and coffee mills.

The alternatives to hydropower generation were continued reliance on diesel or connection to the national grid at Chwele, which is less than 10 km from any portion of the proposed service area. The energy costs as a function of demand indicates that decentralized hydropower is clearly favored over the diesel option except for extremely low utilization rates, and slightly favored over the grid extension option when the utilization rate was less than 0.50 (see Figure 1).

TABLE 2
The Local Component of Hydropower Capital Costs

Type	Location	Size (MW)	Capital Cost ($/kW)	Foreign Exchange Fraction
Large	Remolino, Honduras	125.0	1800	0.67
	El Cajon, Honduras	292.0	2226	0.75
Mini	Guyamal, Honduras	8.0	1383	0.52
	Humuya, Honduras	8.0	2588	0.52
Micro	Providencia, Costa Rica	0.04	6000	0.51

Figure 1. A Comparision of Rural Electric Energy Costs for the Terem Falls project in Western Kenya



Source: Wayne, W. W., and Forsman, A. Evaluation of Small Hydropower Sites in Kenya: Report of Mission to Kenya, 17 March to 9 April 1982, Prepared for the United Nations Departent of Technical Cooperation for Development

Two factors, however, make the grid extension option appear less expensive in this example than it would in most other developing countries. First, all the villages to be served are very close to the existing grid (within 10 km), which considerably reduces transmission costs. Such proximity is frequently not the case in developing countries. Second, the cost of grid energy in Kenya was relatively low ($0.05/kWh in 1982 dollars), since about 83 percent of the country's generation capacity in 1982 was already based on hydropower. Such low costs are usually not the case in other developing countries, which rely heavily on expensive imported oil for power generation. Even with these two factors strongly favoring grid extension, decentralized hydropower remains competitive for capacity utilization rates above 50 percent.

Estimating the value of a decentralized hydropower site when it is incorporated into a large electric grid is often difficult. This estimate usually requires sophisticated utility expansion-planning and cost-of-service models to estimate marginal costs of capacity and energy which can be difficult to apply in developing countries (often due to a lack of accurate data on generation, transmission, and consumption characteristics) or which do not have the capability for accurately evaluating the effects on the main grid of small dispersed power generating systems.

Finally, care must be taken in site assessment to avoid inappropriate applications. In particular, applications involving multiple uses for the water must be carefully examined to be sure the uses do not compete with each other. For example, when hydropower is combined with irrigation systems the use of water for irrigation may impose constraints on the amount of water available for power generation, and vice versa. In these cases determining whether a project is cost effective requires very detailed cost-benefit analyses by competent economists.

CURRENT RESEARCH AND DEVELOPMENT EFFORTS

Decentralized hydropower technology is already well developed and no major breakthroughs are expected or really needed. Research and development has therefore focused on finding ways of reducing the costs of capital equipment and of site assessment.

Various approaches to reducing the cost of decentralized hydropower equipment are being pursued by manufacturers in the United States and abroad. One approach has been standardization of unit designs, which facilitates equipment selection and plant design and construction. Several manufacturers are providing turbo-generating sets as preassembled packaged units, which allows alignments to be made at the factory, installation to be simplified, and overall cost to be reduced. Other

manufacturers have capitalized on the lower cost of mass-produced pumps and used these, with slight modifications, as turbines in sizes from under 1 MW to 2 MW. These designs offer a per kilowatt cost lower than conventional turbine designs, although they are less efficient than conventional designs when operating off their design conditions. Manufacturers are also developing new designs such as modified marine thrusters. As interest in decentralized hydropower installations with a capacity of less than several hundred kilowatts has grown, numerous new, very small companies based in developing countries have entered the field and are providing equipment at a lower cost than established suppliers in the developed countries. Finally, recent advances in electronics have been reflected in new micro-processor controls and monitoring and generating equipment for hydropower plants. These permit increased operating efficiency for projects with storage and reduce maintenance and operating costs.

A second area of research and development interest is reducing the costs of site assessment. To determine the financial viability of a proposed plant, estimates of the capital and operating costs, annual energy output and demand are essential. Although the techniques for obtaining these estimates for large hydropower sites are well developed, these techniques cannot be readily applied to decentralized hydropower projects without creating unacceptably high engineering costs -- the initial costs of analyzing the site and optimizing the plant design can exceed the project's construction and equipment costs. Therefore, international lending institutions are trying to develop approaches based on regional data and general site characteristics as a basis for loan approval[12]. The World Bank has developed techniques (some using satellite photographs) for estimating the number, size, and cost of decentralized hydropower projects that could be developed in a particular region or country under study. The Inter-American Development Bank is adapting a computer program that analyzes water-supply projects to analyze decentralized hydropower projects. These approaches are experimental, however, and have yet to be validated.

Other approaches to reduce the costs of project assessment are being developed by project developers, vendors and engineering firms. Engineering costs have been reduced by adopting standardized plant designs based on key site parameters. In procuring equipment, firms have recognized that it is uneconomic to conduct standard model testing and factory acceptance tests for smaller-sized equipment, and they have adopted instead standard bid specifications that depend on performance guarantees. And finally, rather than hiring individual contractors and carrying out detailed site construction inspections, the net administrative costs may be reduced by having a single general contractor who provides a "turnkey" project with performance and duration guarantees.

OTHER ORGANIZATIONS' ACTIVITIES

So that there is no unnecessary duplication of decentralized hydropower activities, S&T/EY actively co-operates with other organizations. In the years following the 1973 oil embargo a number of development organizations, banks and countries became interested in assessing decentralized hydropower potential in developing countries through studies both country-wide and focused on specific river basins. The United Nations Department of Technical Co-operation for Development (DTCD), a headquarters department under the Secretary-General responsible of executing programs of the United Nations Development Programme (UNDP) has undertaken an ambitious survey of decentralized hydropower resources and the potential for their development around the world. It has conducted fairly extensive decentralized hydropower appraisal studies in 30 countries since 1980, with additional studies planned in 16 countries. The UNDP-DTCD seeks to promote the development of the most promising sites and has indicated its interest in financing decentralized hydropower projects in remote areas of lower-income countries, primarily in Africa.

Several international financial institutions have undertaken decentralized hydropower assessments, including the World Bank, the Asian Development Bank, and the Inter-American Development Bank. The assessments were undertaken with an eye toward identifying and funding specific sites. In addition, the UNDP and the World Bank carried out an extensive series of studies to assess issues and options in the energy sector in a number of countries. In these studies, they reviewed decentralized hydropower's role in addressing energy needs in each country and made recommendations for future activities.

The World Bank's strategy has been to incorporate decentralized hydropower into other sector projects (such as agriculture or rural industrial development) wherever possible. For example, a 1979 World Bank loan to rehabilitate Sri Lanka's tea plantations involved restoring eight decentralized hydropower plants that provided power to the plantations [13]. Regional lending institutions, including the Caribbean Development Bank (CBD) and the African Development Bank (AFDB), have also participated in decentralized hydropower projects. The decentralized hydropower efforts of several international financial institutions are summarized in Table 3.

Through bilateral aid programs, several developed countries including the United States, Germany, Switzerland, and Japan have assessed decentralized hydropower potential in various developing countries. AID's Office of Energy is providing assistance in this area through its Cooperative Agreement with NRECA. Under this agreement NRECA has undertaken regional or countrywide assessments of decentralized

Table 3. Summary of Several Decentralized Hydropower Projects Funded by Lending Institutions (29)[a]

Lending institution	Country	Capacity to be installed (MW)	Amount of loan (US$ millions)	Total project cost (US$ millions)
Asian Development Bank	Malaysia[b]	NA[c]	24.0	NA
	Nepal	2.8	13	NA
	Papua New Guinea	0.120[d]	2.6	NA
	Philippines	5	4.0	NA
	Western Samoa	2	5.0	NA
Inter-American Development Bank	Colombia	35.5	25	62.5
World Bank	Indonesia	7	7.6	13
	Malaysia	15	21	46
	Philippines	NA	NA	3
	St. Vincent	3.4	2.0	13.5
	Sri Lanka	NA	0.83	0.83

Source: Decentralized Hydropower Program staff conversations with senior staff of various international lending institutions.

Table 4. AID Missions with Decentralized Hydropower Projects (30)

Country	Number of project sites	AID financing (US$ millions)	Installed capacity (kW)	Status
Dominican Republic	4	1.620	5000	1 site expected to be operational in December 1986
Ecuador	6[a]	NA[b]	NA	NA
India	3	0.700	500	2 sites expected to be operational in September 1985
Liberia	1	0.150	30	expected to be operational in December 1985
Morocco	1	0.200	200	civil works started; expected to be operational in December 1986
Pakistan	institutional training			
Panama	7	0.780[c]	280	2 sites completed; 5 sites under construction
Peru	10	18.6	6200	5 sites under construction; 3 waiting for approval; 2 up for bidding in September 1985; all 10 expected to be operational by November 1986
Rwanda	1	NA	150	NA
St. Vincent	1	3.3	8000[d]	expected to be operational in December 1986
Thailand	12[e]	1.5	10,000[c]	1 site currently under construction; 3 designed, but found to be uneconomic; 2 up for bidding in August 1985; 6 contracted for design
Zaire	3	2	920	1 site operating; 1 site expected to be operational in December 1986; 1 site under way (completion date unknown)

[a] In addition to the 6 sites, AID financed an institutional training component.
[b] Information not available.
[c] Estimated.
[d] The total project cost is $300 million; the project is being co-financed by the World Bank, European Investment Bank, Caribbean Development Bank, and the Canadian Government.
[e] In addition, AID financed 4 pilot projects, all of which are now operational, with a total installed capacity of 375 kW, at a total project cost of $400,000.

hydropower potential in nine countries. The AID Missions have also financed decentralized hydropower projects, which are summarized in Table 4. The efforts of the other developed countries are often in direct support of efforts by their manufacturers to sell equipment.

While many studies have assessed decentralized hydropower technical potential, relatively little assistance has been provided for planning, implementing, operating, and maintaining such projects. The major effort in this area has been made by the United Nations Industrial Development Organization (UNIDO). In conjunction with the UNDP, UNIDO supports global and regional activities including workshops, conferences, and a decentralized hydropower research/training center for Asia in Hangzhou, China.

Other institutions have been involved in developing guidelines for project appraisal. The Latin American Energy Organization (OLADE) has prepared a series of publications describing various facets of decentralized hydropower plant implementation and UNIDO, in conjunction with OLADE, has prepared Mini Hydro Power Stations, A Manual for Decision Makers.

LESSONS LEARNED

In the past few years individuals and organizations involved in implementing decentralized hydropower projects worldwide have gained a wealth of experience on which others can build, although unfortunately little of this experience has to date been documented. S&T/EY has collected much information during in-country project work and from conversations and correspondence with engineers, public servants, representatives of international financial institutions, and project managers. From these hundreds of sources, a consensus has emerged on the major obstacles to implementing viable decentralized hydropower plants or programs:

- lack of physical data;
- inappropriate designs;
- discriminatory energy policies;
- poor assessment of demand; and
- institutional and management problems

LACK OF PHYSICAL DATA

Data on the physical characteristics of specific basins and sites are poor in many developing countries. Since decentralized hydropower schemes are often located on ungauged watersheds, there is little or no knowledge of the hydrologic characteristics (i.e., rainfall and streamflow) for sizing the plant or for determining the potential costs and benefits. Nor is there detailed data on site topography or subsoil characteristics to accurately guage project feasibility. There are many examples of decentralized hydropower schemes that were not successful because of this. Near Pokhara, Nepal, for example, a 280 kW plant was installed to provide independence from imported fuel, meet the growing power demand of the agricultural project, and ensure a steady supply of electricity 24 hours a day 14. Unfortunately, the plant is forced to shut down for half the year because the flow in the stream is insufficient to generate power even at minimum capacity.

INAPPROPRIATE DESIGNS

Frequently, firms or agencies familiar with large hydropower technologies and design practices will attempt to simply scale these down to implement micro- and mini-hydropower projects. This approach usually results in costs that are higher than they need to be which have given small hydropower projects a reputation for being expensive. Problems arise as a result of requiring a range of increasingly detailed site studies before implementation, relying heavily on imported construction materials and sophisticated imported turbo-generating equipment, developing capital-intensive designs, and depending on overseas consultants and firms that may have little experience in the particular developing country.

For example, equipment of the required size and sophistication for large hydropower schemes is available only from foreign sources, resulting in foreign currency requirements for these projects averaging between 65 percent and 75 percent of total capital cost [15]. By contrast, the foreign currency requirements of decentralized hydropower projects will generally not exceed 50 percent of total capital cost even when the turbo-generating equipment is imported because the civil works components usually can be built with local engineering and materials In addition, several developing countries such as India, Indonesia, Nepal and Thailand are now able to manufacture turbines up to 10 MW locally. These countries also manufacture governing equipment and are preparing to fabricate larger turbines under license with a European firm [16]. The local fabrication of such equipment can reduce the foreign currency requirement for a typical project to 20 percent of capital cost [17].

As another example, the Small Hydel Development Board in Nepal relied heavily on overseas consultants and engineers who were not experienced with small hydropower or conditions in Nepal. As a result, its mini-hydropower plants (1 MW and 5 MW) ranged in cost from $5,000/kW to $11,000/kW. These costs stand in stark contrast to the costs of plants actually implemented by local companies. For these locally designed plants, indigenously manufactured as well as refurbished turbines were used, the engineers had considerable experience both in Nepal and with small hydropower, maximum use was made of local manpower and indigenous expertise, and designs were tailored to the specific site conditions. As a result, the locally designed and constructed micro-hydropower units, as well as the locally designed versions of the 1 MW and 5 MW plants designed by the foreign consultants, cost about $1,000/kW.

In a number of developing countries the decentralized hydropower potential remains untapped because the generation and distribution of electric power is under the exclusive purview of public institutions such as state-owned utilities that are often preoccupied with large power projects and other activities. As a result, the utility may not have the manpower or interest in identifying and developing cost-effective decentralized hydropower projects. In addition, development of decentralized hydropower resources by other agents may be prohibited.

Finally, government policies on energy pricing have also discouraged development. Prices are often subsidized for electricity, diesel oil, kerosene, and other commercial energy products. This subsidization prevents decentralized hydropower from demonstrating its true cost-effectiveness thus retarding its development, particularly by private operators.

POOR ASSESSMENT OF DEMAND

Adequate local demand for the generated power is critical to the viability of isolated projects. Many projects have been uneconomic because productive uses for the energy did not always materialize as assumed. Often sites are selected for political reasons or because the site had suitable physical characteristics rather than for an actual demand for power. In selecting potential sites, it is critical that productive loads exist or have an excellent chance of being created. In the latter case, a significant effort must be made to integrate productive end uses with the project. This integration requires the close coordination of various government agencies or organizations, which is often difficult to achieve.

If there are few productive loads, isolated hydropower projects become a financial burden to the sponsoring agency. The revenue often fails to meet recurring operating and maintenance costs, let alone service the debt or cover depreciation. With grid-connected decentralized hydropower plants, the relatively small increments of power are readily absorbed, usually displacing more expensive oil- or coal-fired generation. Thus insuring a local demand for the power is not usually so critical. However, there is then more direct competition with grid-provided power which may make the decentralized hydropower site less economically attractive.

MANAGEMENT AND INSTITUTIONAL PROBLEMS

Decentralized hydropower projects can suffer the same management and institutional problems that can affect other types of projects in rural areas of developing countries. These problems arise primarily from the lack of trained people for constructing, operating, and maintaining the sites. Other problems arise from difficulties obtaining project financing, obtaining spare parts (or the foreign exchange needed to purchase them), collecting bills, and balancing the requirements of power generation with those of alternative uses for the water such as irrigation.

Institutional issues can arise because there can be entrenched interests in many developing countries favoring alternative power supplies for rural or remote areas such as diesel generator packages or expansion of the existing power grid to those areas combined with additional large power generating systems. These preferences occur because the people responsible for system selection, design, operation and maintenance may not be familiar with small power systems and thus are afraid to recommend them. In addition, the infrastructure in the country for marketing and maintaining the alternatives to small hydropower, particularly diesel generating packages, are usually much better developed that that for hydropower. Diesels are also perceived as being more flexible, since if the expected demand does not materialize they can easily be removed and installed elsewhere. Finally, there is often little or no interest on the part of host government policy makers to actively pursue decentralized hydropower projects because of the perceived difficulties in assessing the costs and benefits of individual projects which translates into additional risks without striking compensating benefits.

Management and institutional issues are particularly difficult to resolve in developing countries because often the government organizations which may contribute to some of the problems are the only ones with the expertise to properly design and operate the systems and may be the only ones with the financial strength to attract funding. Thus even though it may be

desirable to encourage the local private sectors to own and operate decentralized hydropower facilities in rural areas, these sectors may require extensive training and even then may not be able to finance a project. There is no simple resolution to this problem; each country must determine its best balance of public and private sector participation and responsibility.

CASE STUDY OF A SUCCESSFUL DECENTRALIZED HYDROPOWER PROGRAM

To understand the requirements for successful implementation of decentralized hydropower projects, AID has supported the preparation of case studies of several decentralized programs and projects. One of these studies documents a particularly successful private-sector approach in Nepal, where hundreds of decentralized hydropower projects can be found.

Two companies in Nepal -- Balaju Yantra Shala (BYS) and Butwal's Small Turbine and Mill Project -- have each implemented more than 100 plants since their founding ten years ago. The plants were originally designed to provide direct shaft power for agroprocessing machinery -- flour mills, oil expellers, and rice hullers. One factor in the financial viability of these schemes was the inclusion of end-use machinery as an integral part of each mill. Now the plants have been put to other uses: sawmilling, paper-making, crop drying, dyeing of yarn for carpet-making, preparing fruit juice concentrates, and recently, generating electricity. The Agricultural Development Bank of Nepal, with support from the Asian Development Bank in Manila, is actively promoting these micro-hydropower plants by providing loans. The typical total cost for a hydro-mechanical plant including turbine, flour mill, rice huller, oil expeller, penstock, powerhouse, material transport, site design, land, right-of-way, and licensing is on the order of $10,000. If electric power is desired the mechanical equipment for this plant could be replaced with a 5 to 15 kW generator and controls, probably with minor cost savings.

The two companies that first began work on micro-hydropower plants in Nepal initially required technical expertise and financial support which was provided by German, Swiss, and Japanese government agencies and firms. Later, because of the emphasis on a local approach to equipment design and plant implementation, the necessary technology was quickly transferred to local personnel and now six other companies in Nepal have undertaken micro-hydropower projects on their own. Nepali Yantra Shala, which was started by a former employee of BYS, has already implemented about 20 plants. The National Structure Engineering Company has initiated work on an original turbine design without outside technical assistance, and in the

past 4 years has implemented approximately 100 plants [18]. Despite their small size, the micro-hydropower plants in Nepal are already contributing 2 MW to 3 MW of power for the development of the country's rural areas.

These two programs in Nepal have been successful largely because the major obstacles to implementing cost-effective decentralized hydropower projects were carefully avoided:

- The lack of hydrologic data was addressed by relying on local villager experience with the flows in streams and irrigation canals over the years.
- To reduce costs, simple civil designs commonly used with irrigation schemes and traditional hydropower mills throughout the country were used and instead of using imported equipment, all turbines were designed to meet the local site conditions (head and flow) and fabricated locally.
- There were few discriminatory energy pricing policies by the government.
- Management problems commonly associated with small decentralized schemes were avoided by relying on private companies to implement the schemes and on private entrepreneurs to own and manage the installations.
- Demand for the power was ensured by first determining existing needs at a site and then designing hydropower schemes to specifically cater to those needs.

CONCLUSIONS

In many AID-assisted countries, decentralized hydropower is an attractive energy-supply option competitive with alternatives such as diesel generation and grid extension. However four interrelated problems make it difficult for this resource to achieve its full potential.

- Policy development. AID host governments must address policy areas that currently inhibit cost-effective decentralized hydropower development, including price subsidies for alternative energy sources such as diesel, kerosene, and electrical energy supplied by parastatal utilities; restrictions on the ownership and commerce of electric power facilities, including decentralized hydropower plants; lack of energy planning and interagency policy coordination; and the absence of

good data collection and dissemination on power markets, site parameters, and design standards.

- Technical assistance and training. Skills training is needed for local engineers and entrepreneurs in estimating the potential power output at a site; on estimating the potential local market demand for power; on engineering and design, construction, operation and maintenance, and preparation of business plans and loan applications.

- Information dissemination and networking. To help countries avoid the common mistakes, case studies showing economic benefits, the lessons learned, and the management and institutional structures that appear to work well must be prepared and distributed to appropriate implementers and planners.

- Research, development and demonstration. Although the technology itself is well-developed, research is needed to develop tools such as simple computer programs and approaches that will overcome the lack of technical and financial expertise in many developing countries, reduce site assessment costs, and provide credible justification of project costs and benefits to potential lenders.

AID's energy assistance resources are limited. To maximize the effect of these resources, USAID should focus its efforts on developing a portfolio of technically and economically viable and attractive projects in those countries where the institutional, technical, and financial characteristics most favor such projects. A strategy for developing this portfolio is discussed in the next section.

[1] AID Policy Paper on Energy; US Agency for International Development; July, 1984

[2] R. Sadove, Senior Energy Advisor, World Bank, Luncheon Remarks, April 4, 1985

[3] The Energy Transition in Developing Countries, Washington, D.C., The World Bank, August 1983, p. xix

[4] J. Sullivan, S&T/EY, based on the assumptions:

- Current Power Generating Capacity in AID-assisted countries = 84,000 MW
- Annual Power Generation Growth Rate = 7 percent

- Generating System Capital Costs = $1,200 to $1,800 per kW.

[5] These programs are described in detail in AID Office of Energy. FY86-FY88 Program Plan and Program Initiatives. Discussion Draft. August 5, 1985.

[6] "Remote Power Market Is Predicted to Swell," Renewable Energy News, July, 1985

[7] These definitions are somewhat arbitrary, and are presented here to assist in conceptualizing the ways these systems can fit into a country's energy resource mix. It should be noted that other assistance organizations may define these terms differently. For example, the UN differentiates between mini/small-hydropower systems (which are of a size and application warranting external assistance) and micro-hydropower (which are small and essentially local and which do not warrant external assistance).

[8] Small Hydroelectric Components in Irrigation and Water Supply Projects; International Bank for Reconstruction and Development, International Development Association; Energy Department Note No. 60; July, 1985

[9] For example, an Army Corp of Engineers study estimated the costs of mobilization and demobilization of an overseas contractor for a 120 kW scheme in Micronesia to be almost $6,000/kW which was equal to all the other projected site costs.

[10] Charles T. Main, Inc. Updating of the Hydroelectric Potential in Honduras, June 1984
Canadian Energy Development Systems International (CEDSI), Small Scale Hydro Prefeasibility Study, March, 1985

[11] Wayne, W. and Forsman, A., Regional Assessment of Small Hydro-Power Sites in Kenya: Report of Mission to Kenya, 17 March - 9 April 1982, prepared for the United Nations Department of Technical Co-operation for Development.

[12] For example, Tudor Engineering Company recently completed Regional Assessment of Small Scale Hydropower: A Methodology, for the World Bank, August, 1983

[13] Based on conversations with senior staff of the World Bank and other international lending institutions by Decentralized Hydropower Program staff

[14] Based on visits to Nepal by NRECA staff members Allen Inversin in February 1984 and Elizabeth Graham in April 1985

[15] Based on Decentralized Hydropower Program staff experience.

[16] Based on visits to Nepal by NRECA staff members Allen Inversin in February 1984 and Elizabeth Graham in April 1985

[17] Based on Decentralized Hydropower Program staff experience.

[18] Based on A. Inversin conversations with Andreas Bachmann of UNICEF/Nepal who documented several efforts to implement small-hydropower schemes in Nepal.

This chapter summarizes the strategy that S&T/EY will follow for developing decentralized hydropower potential within its limited resources. First it describes the general approach. Then, it summarizes the activities needed to implement the strategy. Finally, it presents the budget and schedule for these activities.

GENERAL APPROACH

Because of its limited resources, S&T/EY's strategy for encouraging cost effective decentralized hydropower development will have two components. First, it will concentrate on financing country-needs studies in two countries to identify a portfolio of "bankable" projects -- those projects that have been analyzed in sufficient detail that they will attract follow-on funding from private sector, international lending, and AID Mission organizations. These organizations will then finance detailed feasibility studies, project construction, operation, and related activities.

Second, the decentralized hydropower efforts will be merged during FY86 into the following S&T/EY Program Initiatives: Small Utility-Scale Power Systems, Industrial and Village-Scale Power Systems, Energy for Irrigation Pumping, Energy for Agroprocessing and Other Rural Industries, and Irrigation and Energy Planning in River Basin Development. In this way S&T/EY can ensure that decentralized hydropower systems are assessed together with conventional energy options (e.g., diesel generators) and that the hydropower option is used wherever it is the most cost-effective.

STRATEGY IMPLEMENTATION

Implementing this strategy will require three activities:

- Identify target countries having both the physical and the institutional potential for significant decentralized hydropower development;
- Conduct country-needs studies in the target countries to identify and evaluate attractive decentralized hydropower sites; and
- Broker follow-on efforts to promote development of attractive sites by private investors, lending institutions, and AID Missions.

These activities are discussed in detail below.

STEP 1: IDENTIFY PRIORITY COUNTRIES

S&T/EY will focus its efforts for FY86 on two countries having significant potential for successful implementation of decentralized hydropower projects. While many more than two have significant decentralized hydropower potential, the available funds will not support additional efforts. These two countries will be selected on the basis of physical potential, energy need, and investment climate. One country, Madagascar, has already been selected; the second will be selected by the end of April, 1986. The procedure for selecting countries is as follows.

First, the relative physical potential for decentralized hydropower in individual AID-assisted countries was determined. Although such a determination would normally require extensive analyses and on-site visits that are beyond the resources of this effort, an approximate estimate can be developed using two approaches. The first approach assumes a country's decentralized hydropower potential density (in kW/km^2) is proportional to its total hydropower potential density, as estimated by the World Bank and other organizations. The second approach assesses the potential based on country topography and runoff estimates. The procedures for these approaches are detailed in Annex C. Both approaches gave approximately the same results, identifying 37 countries with significant decentralized hydropower potential.

For these 37 countries, both energy need and investment climate were evaluated to determine the existence of a market for the power and the absence of significant institutional barriers. Energy need was evaluated using the projected growth rate for energy demand for the 1985-1990 period, and the estimated percentage of electric power generated from oil in 1990. Investment climate was evaluated using estimates of host government support for decentralized hydropower, local capability to implement these projects, a favorable climate for private-sector investments in power generation, and active donor interest, particularly on the part of the responsible AID Mission. The results of the energy need and investment climate assessments for the 37 countries with significant physical potential are shown in Figure 2 and detailed in Annex C.

On the basis of these assessments, 17 countries, listed in Table 5, were identified as having the best potential for decentralized hydropower development. One of these countries, Madagascar, has been selected as a target country. Madagascar was selected for three reasons. First, the World Bank indicated that is was very interested in funding cost-effective power sector projects in that country beginning in early 1986. Second, the AID Mission had significant PL 480 funds available (approximately US $25 million) for productive investments including decentralized hydropower. Finally, the Government of Madagascar indicated it was interested in exploring an enhanced private sector role in the energy sector, possibly beginning with decentralized hydropower projects.

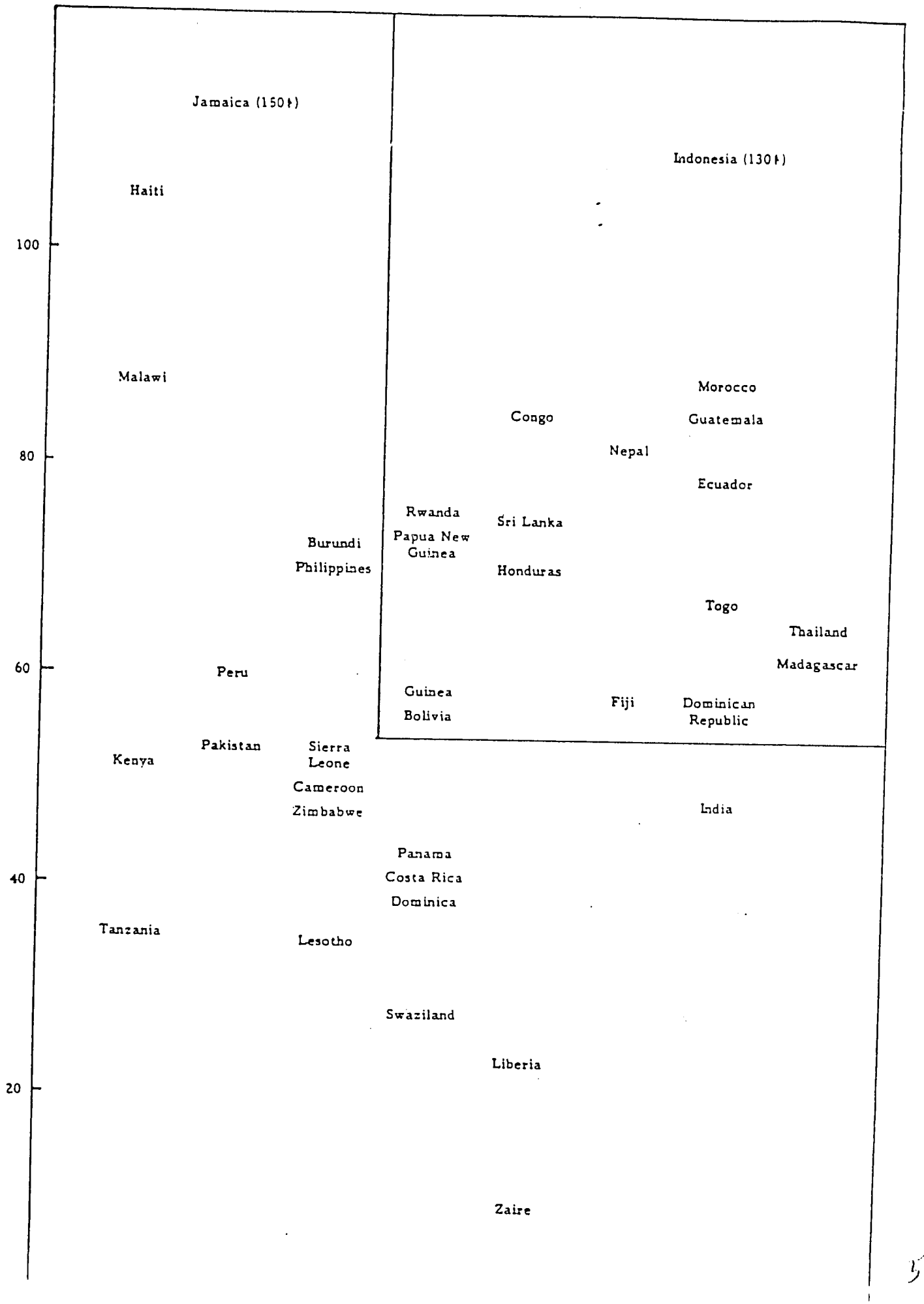

Jamaica (150+)
Indonesia (130+)
Haiti
100
Malawi
Morocco
Congo
Guatemala
80
Nepal
Ecuador
Rwanda
Sri Lanka
Papua New Guinea
Burundi
Philippines
Honduras
Togo
Thailand
60
Madagascar
Peru
Guinea
Fiji
Dominican Republic
Bolivia
Pakistan
Sierra Leone
Kenya
Cameroon
Zimbabwe
India
Panama
40
Costa Rica
Dominica
Tanzania
Lesotho
Swaziland
Liberia
20
Zaire

Table 5. Priority AID Countries for Decentralized Hydropower

Africa and the Middle East	Asia and the Pacific	Latin America
Congo	Fiji	Bolivia
Guinea	Indonesia	Dominican Republic
Morocco	Nepal	Ecuador
Madagascar	Papua New Guinea	Guatemala
Rwanda	Sri Lanka	Honduras
Togo	Thailand	

One additional country will be selected for prefeasibility studies from the 16 other countries on the list. This selection will be made after in depth discussions within AID and with experts from other international organizations, and will be based on the presence of favorable factors such as were present in Madagascar. This selection will be made by the end of April, 1986

S&T/EY recognizes that this approach may result in countries having significant decentralized hydropower potential being bypassed initially. However, it feels it is at this time far more important to identify a pair of attractive countries and concentrate its limited resources to insure its efforts will have a significant impact. Then, using the examples set in these two countries, additional efforts can be mmounted in other countries funded by other organizations such as the AID missions with the guidance and advice of S&T/EY.

STEP 2: CONDUCT COUNTRY-NEEDS STUDIES.

For the two countries identified in Step 1 country-needs studies will be carried out; the studies will consist of preliminary reconnaissance and prefeasibility studies. These will be conducted by S&T/EY in coordination with host country energy and development organizations (both public and private), private U.S. organizations, AID Missions and geographical bureaus, and other lending and assistance organizations such as the World Bank. The preliminary reconnaissance will use existing reports, discussions with host country and other experts, and -- where practical -- in-country and on-site visits to identify the most promising decentralized hydropower sites. The sites will be selected on the basis of answers to the following questions:

- Will the site serve current or planned high priority development activities that have energy needs?
- Is the physical power potential sufficient to supply all or a significant portion of the identified needs economically, compared with alternative energy sources?
- Is the investment climate favorable, with interested investors, a supportive institutional and policy environment, and project implementation capabilities, particularly in the private sector?

For each site which has an affirmative answer to these questions, a prefeasibility study will be carried out to expand the reconaissance findings with more detailed assessments of the technical, financial, and institutional factors affecting site development. The output of this effort will be a portfolio of "bankable" projects representing attractive investment opportunities, which will be presented to prospective project developers and lending institutions (see Table 6).

Table 6. Hypothetical Examples of Summary of Results from Prefeasibility Activities

Site name	State or province	River	Capacity (kW)	Head (m)	Type of scheme[a]	Capital cost (US$ million)	IRR (%)	Construction period (months)	Comments
1. Bishala	Central Shivu	Kisop	900	42	R	1.65	12	14	integrated with irrigation scheme covering 850 ha
2. Wanigan	Central Shivu	Barama	1400	15	R	2.14	15	12	replace diesel which supplies a sawmill, a furniture manufacturer, and a small town (delayed grid-interconnect probable)
3. Kagamina	Marobe	Laugaira	550	67	S	1.38	10	25	to power agro-processing industry to complement major AID maize project
4. Sarin	Kenlugo	Misima	2400	28	R	3.67	9.1	19	to supplement grid-supplied energy serving government center and densely populated area of 30,000

[a]R = run-of-river, S = storage (with dam).

The prefeasibility study for Madagascar has been completed, and the Executive Summary of that study is presented in Annex D. This study serves as a good example of the methodology and procedures which will be used in this type of effort. First, the overall development goals and activities of the target country are assessed. Next, the national energy needs and resources are assessed and projections of future requirements are reviewed or developed. Then, an evaluation of how and where decentralized hydropower provides the most cost-effective means to meet this need is made, based on detailed evaluation of specific regional needs and of specific sites.

STEP 3: BROKER FOLLOW-ON EFFORTS

S&T/EY will use the experience and contacts it has developed in the past 4 years of decentralized hydropower efforts, together with the prefeasibility study results, to identify and bring together potential project developers and lenders and obtain commitments to implement specific projects. Where necessary, it will reduce obstacles to implementation by offering technical assistance and training to local engineers and entrepreneurs interested in site assessment, local power market assessment, construction, operation and maintenance. S&T/EY will also provide training for host government personnel in energy planning to help eliminate legal or regulatory barriers to site development, and it will provide computer models and other aids to streamline the technical and financial assessment process.

An important part of this effort will be the encouragement of host country private sector individuals and organizations whenever they are willing and able to play a major role in the financing and operation of these projects. This involvement will begin in the initial assessment stage through discussions with interested private individuals and organization to determine their perceptions of the risks and rewards of decentralized hydropower projects and the obstacles they perceive to its development. Then, they will be given evaluations of the esitimated costs and benefits of specific sites to assist them in determining whether they are attractive enough to justify further investment of time and money. Finally, S&T/EY will assist them in financing the project by introducing them to potential lenders and by helping them prepare loan documents.

RESOURCES

The financial resources available for FY86 activities are residual funds from FY85, since S&T/EY has no FY86 funds for the Decentralized Hydropower Program. The budget estimates given in Table 7 for the period October 1, 1985 to September 30, 1986 are based on a projected availability on October 1, 1985 of $475,000. The primary support is provided by the National Rural Electric Cooperative Association (NRECA) under a Cooperative Agreement (AID/DSAN-CA-0226). NRECA provides skills in a number of fields, including

Table 7.
Summary Budget for the Decentralized Hydropower Program for Fiscal Year 1986

ITEM	AMOUNT
1. NRECA base support	$415,000
2. Country B subagreement	60,000
TOTAL	$475,000

engineering, economics, product development, program management, data development and analysis, information network maintenance, administrative support and other areas as required. When required outside consultants are also engaged.

As an indication of its commitment to the Cooperative Agreement, NRECA provides an in-kind contribution, which currently averages over $2,000/month. In addition to this contribution, NRECA has supplemented the Madagascar team salaries from its own overhead funds to ensure adequate time for preliminary efforts before departing for Madagascar.

These funds may be supplemented by AID Mission funds, which will allow a more extensive study. This was the case in Madagascar. The potential for such support, however, cannot be determined until the second country is identified.

SCHEDULE

The expected schedule for remaining decentralized hydropower efforts is summarized in Table 8. The final report on all efforts supporting decentralized hydropower will be presented to AID by September 30, 1986.

Table 8.
Proposed Activity Schedule for the Decentralized Hydropower Program for Fiscal Year 1986

Country A: Madagascar	
October 21, 1985	Present draft final report to S&T/EY
November 4, 1985	Receive S&T/EY comments
December 8, 1985	Complete final report; brief AID develop next step strategy
Country B: (To be determined)	
April 30, 1986	Identify final country and agreeon scope of work
June 13, 1986	Complete team selection
July 11, 1986	Complete interim report; brief AID; team departs
August 29, 1986	Present draft final report to S&T/EY
September 12, 1986	Receive S&T/EY comments
September 30, 1986	Complete final report

ANNEX A. SUMMARY OF USAID'S DECENTRALIZED HYDROPOWER EXPERIENCE SINCE 1980

THE DECENTRALIZED HYDROPOWER PROGRAM

In 1980 the U.S. Agency for International Development (AID) Bureau for Science and Technology, Office of Energy (S&T/EY) signed a Cooperative Agreement (AID/DSAN-CA-0226) with the National Rural Electric Cooperative Association (NRECA). This agreement provided the Decentralized Hydropower Program services in:

- Administration -- formulate program activities, execute subcontracts, arrange workshops, develop training programs, and carry out field support activities;
- Project identification and design -- identify potential sites, conduct prefeasibility studies, carry out detailed feasibility studies;
- Database development -- survey state-of-the-art in developing and developed countries; identify equipment infrastructure; assemble databases of skills and available technology; and prepare manuals, bulletins, and resource directories.

During the past five years a substantial amount of knowledge and experience were gained and many services were provided to encourage the cost-effective development of decentralized hydropower resources in AID-assisted countries.

PROGRAM RESULTS

As part of the program, four technical workshops were held worldwide -- Quito, Ecuador in 1980; Bangkok, Thailand in 1981; Abidjan, Ivory Coast in 1982; and Mbabane, Swaziland in 1983. Over 400 developing country engineers, planners, and project managers met to exchange information and experiences and to learn about the principles and practices of decentralized hydropower. These workshops included classroom and field exercises and team problem-solving.

Two small but important seminars were conducted in Washington, D.C. One in March 1981 focused on the issues and opportunities associated with financing decentralized hydropower systems in developing countries. This

was attended by invited representatives of the international financial community. The other in July, 1982 brought together developers and manufacturers from the U.S. private sector to discuss problems with and opportunities for decentralized hydropower development in AID-assisted countries.

Training assistance was provided in three ways. One was by the transfer of technology to the i.-country counterparts by AID technical assistance teams. The second was by several week-long study tours which familiarized developing country engineers with U.S. hydropower equipment manufacturers and decentralized hydropower projects. The third was by developing and presenting a rigorous two-week course in hydrology in Manila, the Philippines. The course was attended by selected government and private-sector engineers involved in national decentralized hydropower programs in the Philippines, Indonesia, Malaysia, and Thailand.

To document its workshops, its findings in country-specific efforts, and the experience that it has gained since its inception, the Decentralized Hydropower Program has prepared a number of publications:

- Case studies on various approaches to implementing decentralized hydropower plants in Pakistan, Nepal, and Zaire;
- Prefeasibility and feasibility methodologies and guidelines for evaluation, environmental assessment, and hydrologic analysis;
- Special studies -- a study on decentralized versus centralized management, an economics handbook, a directory of manufacturers, and a micro-hydropower sourcebook;
- Workshop proceedings from Ecuador (English and Spanish), Thailand (English), Ivory Coast (English and French), and Swaziland (English);
- Technical articles -- economically productive uses of energy, state-of-the-art in electrogenerating equipment, approaches to rural development; and
- Country reports -- documentation of the team technical assistance services and attendant recommendations.

The Decentralized Hydropower Program has developed information on decentralized hydropower around the world and has used it to prepare training and reference materials for planners and engineers and to respond to the mumerous requests for information from individuals and organizations active in decentralized hydropower in developing countri s. This information is consists of:

- A library -- holdings of nearly 4,000 books, reports, newspaper and journal articles, and periodicals on all aspects of decentralized hydropower, rural electrification, economic analysis of development projects, and other energy technologies;

- Slides -- over 2,000 slides documenting the design, implementation, and operation of decentralized hydropower plants around the world; and

- An information network -- a network of research institutes, universities, government agencies, development organizations, manufacturers, and individuals involved in decentralized hydropower; a talent bank of over 200 specialists in engineering, economics, sociology, and other fields with appropriate language and overseas expertise.

In response to USAID Mission requests, the Decentralized Hydropower Program has provided short-term assistance to the 21 countries listed in Table A1.

Table A.1
Countries in Which the Decentralized Hydropower Program has Provided Technical Assistance Since 1980

Bangladesh	Ghana	Madagascar	Rwanda
Burundi	Guinea	Morocco	Sudan
CapeVerde	Honduras	Nepal	Thailand
Dominica	Indonesia	Pakistan	Togo
Dominican Republic	Lesotho	Panama	Tunisia
	Liberia	Peru	Zaire

ANNEX B. FACTORS AFFECTING THE FEASIBILITY OF DECENTRALIZED HYDROPOWER

The feasibility of a decentralized hydropower project are country- and site-specific. The critical physical, economic and institutional factors affecting project feasibility are reviewed below. Where possible, typical numerical ranges are offered as a guide to project appraisal [1].

PHYSICAL FACTORS

Hydraulic energy (usually electrical or mechanical power) can be produced where a flow of water undergoes a drop in elevation (known as the head). Flow, river slope, accessibility, transmission distance, are soil conditions are additional physical characteristics of a particular site which will affect the project's costs and benefits.

As a general rule, the cost of developing a hydropower site is inversely related to the head under which the turbine would operate. The lower the head, the larger the flow that must be handled and the larger and more expensive the turbines required (although in many cases the civil works for low head systems will be cheaper than for high head systems, partially offsetting the more expensive turbine). As a "rule of thumb", a site should have a head of at least 2 meters for hydropower to be feasible, with most sites having heads between 3 and 50 meters.

FLOW

The flow at a site is a function of the rainfall pattern, drainage area, and runoff characteristics, which can be summarized by flow-duration curves. To estimate the flow accurately, a country should have at least 10 years of good flow data on large rivers and of rainfall data. Generally flows of 0.5 to 100 cubic meters per second for at least 2000 hours per years are considered desirable. The size of a drainage basin necessary to produce year-round flow varies from roughly 1 km^2 in wet, tropical climates to over 200 km^2 in dry climates. Preferably, a reasonable flow should be available year-round, because an extended dry season with no power output may make the project uneconomic. This is particularly true for isolated sites not connected to a utility grid. For grid-connected schemes, the possible displacement by hydropower of

expensive oil-based generation could make even an intermittently operating plant a viable project.

RIVER SLOPE

Most decentralized run-of-river schemes are located over a stretch of river, rather than at a single drop. The cost of the power canal and penstock necessary to produce the head required for power generation is a direct function of the river slope. For a project to be viable, a minimum stream slope of about 5 percent is usually required.

ACCESSIBILITY AND TRANSMISSION DISTANCE

Adequate trails or roads must be available to a potential decentralized hydropower site to allow initial investigation and subsequent construction work. In addition, to keep transmission costs reasonable, the distance from the site to the load center(s) should not be too great. Generally speaking, the maximum transmission distance should not exceed 5 km for a 50 kW site or 10 km to 15 km for a 1,000 kW site.

SOIL CONDITIONS

Topsoil and subsoil conditions affect the feasibility of small hydropower plants because of their effects on water sediment and thus on plant and equipment lifetimes. Catchment basins with significant agricultural area and with little vegetation to hold the soil can suffer soil erosion which results in large amounts of sediment in the river. If the small hydropower site includes a dam, then the settling of the sediment behind the dam caused by the decrease in river flow rate there will either shorten the life of the project, or will necessitate frequent and possibly expensive cleaning out. For run-of-river plants without a dam the sediment flowing through the turbine will cause blade erosion and thus shorten the equipment life. If settling basins are constructed to prevent this they will increase the site costs and may require frequent cleaning out, thus again increasing capital and operating costs.

ECONOMIC FACTORS

The primary economic factors that influence the feasibility of a project include capital and operating costs (compared with alternative systems), the usage rate, the economic discount rate or internal rate-of-return, and the financial performance of the project.

CAPITAL AND OPERATING COSTS.

Although decentralized hydropower capital costs are highly site-specific, an idea of the possible range of costs is provided in Table B1. This table shows the actual installed costs for recently installed plants in developing countries of 100 kW and larger. It indicates that such plants can cost between $860/kW and over $6200/kW.

A study for the World Bank Energy Department gave the following ranges of capital cost estimates:

Turbine-generator and controls	$300 - $600/kW
Power factor and sub-station equipment	$100/kW
Remote control equipment	$20,000/unit
Civil Works	$100 - $2,000/kW

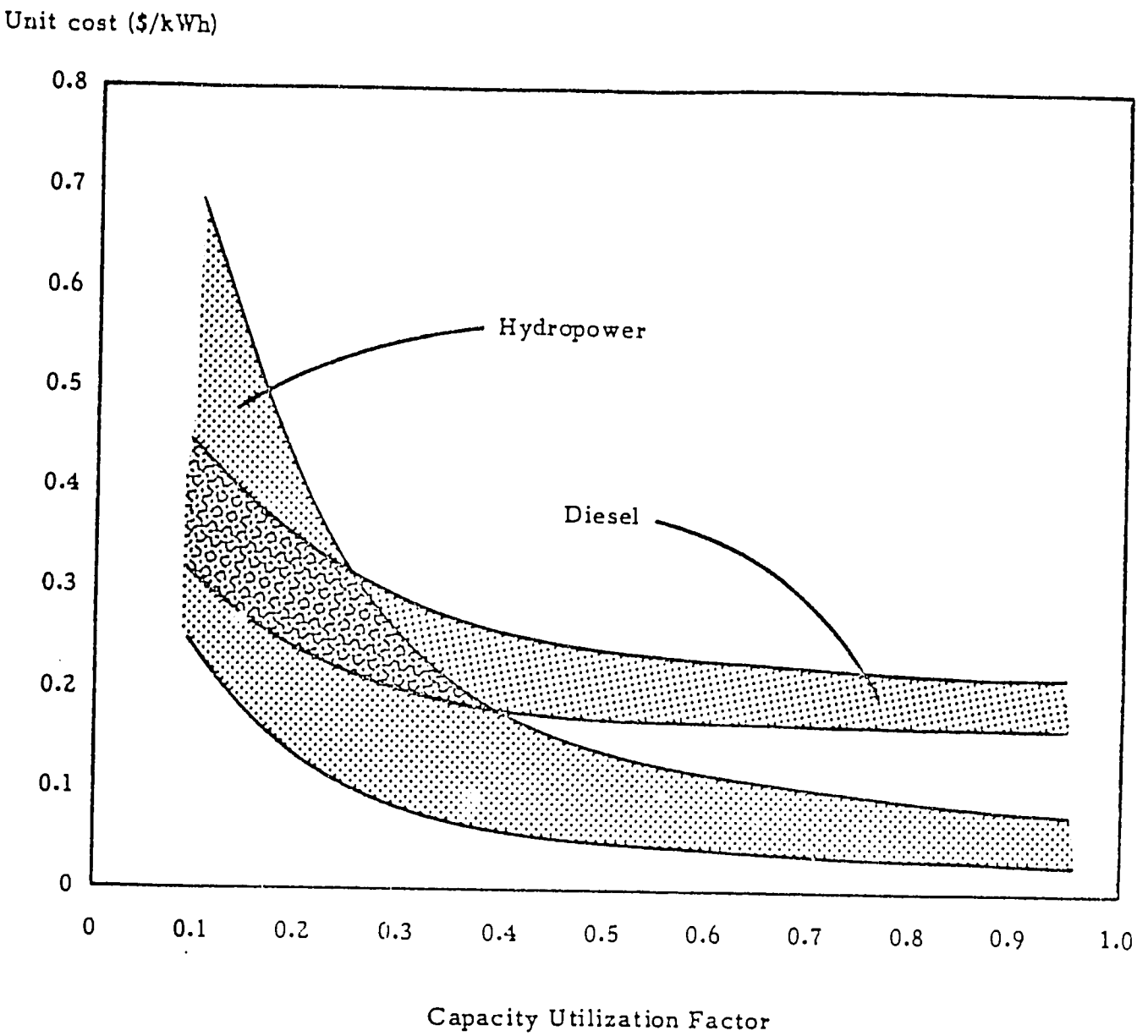
To these estimates must be added indirect costs which can range from $100/kW to several thousands of dollars per kW, depending on the specific site.

Annual operating costs for decentralized hydropower sites typically range from 1.5 percent to 2.5 percent of capital costs, although wide variations from this range are quite possible. These costs include operators' salaries, administration, and routine maintenance. There are of course no fuel costs.

A common alternative to hydropower for isolated energy loads is diesel generation. Capital investment costs are usually much less for diesel generation because it requires minimal construction of civil works or supporting infrastructure and can be located close to scattered and small-scale applications. Depending on unit size, the installed capital cost will run anywhere between $700/kW and $1,200/kW installed, or roughly one-third the cost of comparable hydropower installations.

Operating costs for diesel generation, however, are significantly higher than those of hydropower primarily because of high fuel costs. Unfortunately estimates of operating cost elements are either unavailable or unreliable, especially for the operation of diesel equipment in isolated areas for relatively small applications. The delivered cost of diesel fuel in rural areas is generally assumed to be about $0.30/liter, while fuel consumption for this capacity range can vary between 0.4 liters/kWh to 0.6 liters/kWh, depending on the rating at which the engine is run and the

Figure B1.
A Comparison of Unit Generating Costs



Note: Costs are for a hypothetical 100 kW plant assuming:

- discount rate = 12 percent
- plant life = 15 years for diesel; 35 years for decentralized hydropower
- Annual non-fuel operating and maintenance costs equal 2 percent and 4.5 percent of capital costs for hydropower and diesel, respectively

degree to which it is maintained. A reasonable fuel cost range is therefore $0.14/kWh to $0.18/kWh.

PLANT LIFE.

Another variable that affects a cost comparison of decentralized hydropower with diesel is plant life. Although the hydropower plant operating life experience in developing countries is not as well documented as that in developed countries, many hydropower plants installed in the 1940s and 1950s are still operating. A reasonable estimate is therefore about 35 years.

Diesel generating sets have exhibited much shorter lifetimes in developing countries. Although their theoretical life may be 20 years or more, in practice they often last less than ten years because of heavy usage rate and poor maintenance. Experience has indicated diesel generating set lifetimes ranging from six years to twenty years. The World Bank, in a study of diesel and hydropower generating alternatives in Madagascar (discussed in more detail later) used a diesel lifetime estimate of ten years, which is reasonable for small remote systems in developing countries.

CAPACITY FACTOR

Because hydropower is so capital intensive, annual costs for operation, maintainance, and capital are fixed to a large degree. Thus, the cost per kilowatt-hour is inversely proportional to the usable output. For grid-connected systems, the capacity factor (or usage rate, or load factor) is usually high since the grid will normally absorb the plant's power whenever it is available. For isolated systems, load factors are typically lower, sometimes under 10 percent. A random sampling of capacity factors for seven Indian and Philippine decentralized hydropower sites shows a range from 0.11 to 0.83. Even a single site can have wide variations in capacity factor from year-to-year due to fluctuations in river flow and local demand. A 250 kW plant in the Dominican Republic between 1973 and 1980 showed a variation in capacity factor from 0.44 to 0.83, with an average of 0.61.

The wide variation of annual capacity factors, even for a single plant, may be due to a lack of water or a lack of demand. Water may sometimes be inadequate because of poor hydrologic analysis, poor project design, or dry seasons and drought. Low demand can result from the absence of a stable industrial load or from very "peaky" demand patterns.

This can often be corrected by several means. Programs can be instituted to promote income-producing electricity usage. Load-leveling techniques can also be used to improve energy usage patterns. Where capacity limits are reached during peaks but capacity utilization is low, load management techniques can be used to "shave" peak loads and fill valleys in the load curve. The costs and benefits of such options must however be carefully evaluated to determine if they are truly economic and practical to implement.

The effect of capacity utilization on the economic competitiveness of decentralized hydropower is illustrated in Figure B1. Average values are used for capital costs, useful lifes, and diesel fuel cost, although capital costs and the cost of diesel oil vary widely. This example indicates that, on the average, the break-even point between selecting diesel or hydropower will usually fall somewhere between a 20 percent and a 40 percent capacity factor.

DISCOUNT RATE

Another factor that strongly influences the economic feasibility of decentralized hydropower is the discount rate. As discount rates increase, decentralized hydropower becomes less competitive with diesel and other thermal alternatives, which generally have low capital costs and high variable costs. The effect of discount rates on the competitiveness of energy-supply alternatives is demonstrated in Figure B2. Using data from the example given in Table B2, the present worth costs of the hydropower and diesel alternatives at a 50 percent capacity factor are plotted. The "crossover" discount rate, where the present worth cost is equal for both alternatives, is 22 percent in this example. Therefore, if the cost of capital is greater then 22 percent, diesel is the choice; if less, hydropower is the choice. At a 20 percent capacity factor, however, the crossover rate is much lower (11 percent), since the diesel fuel cost is substantially reduced, while the hydropower cost does not change.

Given typical values for capital costs, project life, fuel cost, and capacity factor, the crossover discount rate between decentralized hydropower and diesel will generally fall between 14 percent and 20 percent. Discount rates used for project analysis in the developing countries typically are in the 8 percent to 15 percent range. This implies that decentralized hydropower can be economically viable for these countries in many cases.

Table B.1
Installed Capital Costs for Selected Plants (1984$)[1]

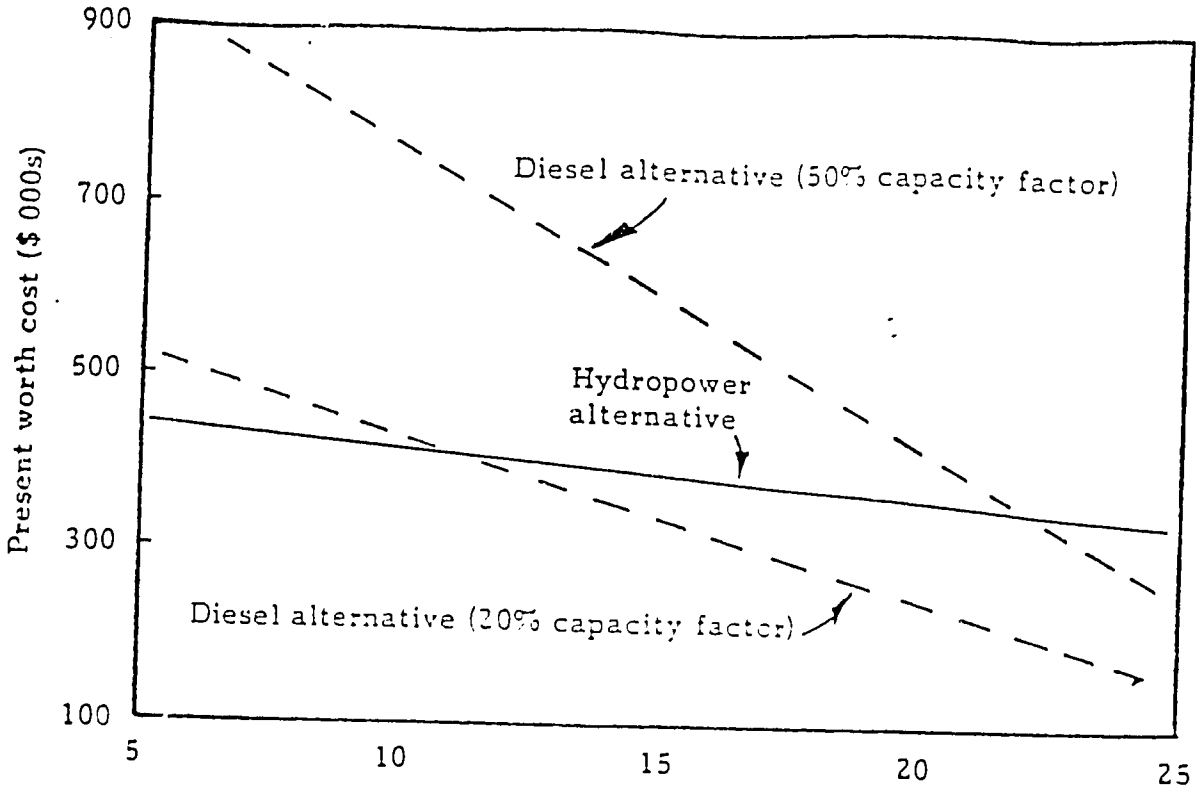
Location	Capacity (kW)	Year of Installation	Installed Cost (1984$/kW)
Thailand	800	1982	3192
Thailand	100	1982	1064
Ecuador	400	1982	2464
Ecuador	400	1982	3024
Nepal	200	1982	1008
Nepal	120	1982	1008
Philippines	100	1980	945
Zaire	320	1976	3082
Indonesia	100	1976	1984
Indonesia	160	1978	863
Indonesia	100	1978	1583
Indonesia	100	1978	1840
Indonesia	575	1979	3451
Indonesia	210	1979	5853
Indonesia	185	1979	6217

Sources: Clark, P. "Cost Implications of Small Hydropower Systems," Small Scale Hydropower in Africa, proceedings of a workshop held in Abidjan, Ivory Coast, March 1-5, 1982; National Rural Electric Cooperative Association, 1982

Subroto, I., et al, "Micro-Hydropower Plants in Indonesia," Small Hydropower for Asian Rural Development, proceedings of a workshop held in Bangkok, Thailand, June 5-11, 1981, NRECA and AIT, 1983

[1]Includes mechanical, civil, and electrical equipment, but no transmission equipment or financing charges.

Figure B2.



Note: Data for this figure developed from a site analysis in the Dominican Republic by Decentralized Hydropower Program staff

Table B2.
Comparative Economic Analysis

Comparative Economic Analysis of Small Hydropower and Diesel Generation for a 100 kW Power Station in Madagascar (38)

	Hydropower	Diesel
Installed cost (US$/kW)	4000	950
Life of investment (yrs)	35	10
Capital recovery factor	0.104	0.163
kWh/kW installed/y (50% load factor)	4380	4380
Costs		
Depreciation (US$/kW/yr)	414.8	154.6
Staff (US$/kW/yr)	2.9	29.2
Operation and maintenance (US$/kW/yr)	18.0	44.7
Overhead (US$/kW/yr)	37.9	49.1
Total fixed costs (US$/kW/yr)	473.6	277.6
Fixed costs/kWh (US$/kWh)	0.108	0.06
Variable costs/kWh (US$/kWh)[a]	0.001	0.14
Total (US¢/kWh)	10.91	20.62

[a]Diesel = FMG 186.0/liter; exchange rate = FMG 625.0/US$; kWh/liter = 2.5; data are from 1984.

Source: Unpublished World Bank report.

FINANCIAL VIABILITY

Financial viability applies both to raising initial capital and covering operational costs. The developer must be in a credit position to borrow funds, which may be difficult because foreign exchange is likely to be involved. Decentralized hydropower projects at the larger end of the capacity scale may require up to 50 percent of the initial capital in hard currency. At the operational level, a project should be self-sufficient, with revenues at least adequate to cover operation and maintenance. Such self-sufficiency implies that the hydropower energy cost is more attractive to consumers than the cost of alternative energy options (for example, diesel or kerosene), and that consumers are able to pay this cost. For isolated projects, there generally must be an "anchor" load -- preferably where the demand is continuous and is used for an economically productive activity -- to establish a financial return sufficient to pay for the system.

In the past, many decentralized hydropower systems were implemented without being financially viable, since it was felt that resulting socio-economic benefits justified the investment. While this in principle is justifiable, in practice these systems were at risk to government financial crises which forced shutdowns. In addition, it was almost impossible to attract private sector investors to such projects because of the high political and financial risks.

NET SOCIO-ECONOMIC BENEFITS

In addition to directly quantifiable costs and benefits evaluated in financial analyses, power projects in developing countries usually have "surplus" benefits to consumers or producers which may or may not be quantifiable in an economic analysis. Moreover, there are other intangible benefits that are generally not quantifiable. These so-called "merit goods" are social benefits to the nation as a whole. Government or donor policies tend to define these benefits, which, in the case of the electrification projects, could include advances in social or political integration and stability, improvements in the economic standing of a disadvantaged region or minority, or the elimination of a critical infrastructural bottleneck. If these are sufficiently large, a project may be good even if the revenues do not cover the expenses, and thus may require a subsidy, usually from the government. While this is proper in principle, recent experience shows that developing countries cannot afford to permanently subsidize such public services. A more advantageous approach may involve a temporary subsidy during the early years of a project, but one combined with direct activities to promote productive, income-producing uses of

power that will enable consumers to afford the cost of electricity over the long run.

INSTITUTIONAL FACTORS

Institutional factors affecting decentralized hydropower viability include government policies, project management capabilities, and cultural factors.

GOVERNMENT POLICIES

Except for very small schemes, decentralized hydropower development usually requires the active support of the national government. However, the government need not be directly involved in project development. Instead, the government can promote development by, for example, enacting policies and laws to encourage private-sector or local development of hydropower, by planning river-basin development schemes, or by developing national standards and standardized designs. Generally, decentralized hydropower programs will be more successful where national regulations do not restrict the authority to generate or sell power. In many countries, subsidized prices for kerosene, diesel, or electricity make decentralized hydropower financially uncompetitive even though it is less costly in real economic terms. The elimination of these price subsidies could prove a significant boost to decentralized hydropower and other renewables.

PROJECT MANAGEMENT

Where national institutions have implemented projects, the technical and managerial skills have sometimes been inadequate. Many projects have suffered from poor design, excessive cost, or inadequate post-commissioning management. To increase the effectiveness of project implementation and reduce costs, therefore, the authority to develop and operate projects should be delegated to local management. The selection of financially and economically profitable projects could best be ensured by seeing that there is a vested, private interest in each project. To this end, high priority should be given to establishing in-country engineering and contracting skills, as well as establishing local community management capabilities in such areas as plant operation, load management, and metering and tariff collection.

CULTURAL FACTORS

In a number of traditional societies, harnessing waterpower is a familiar concept. The basic components associated with hydropower -- diversion weirs, canals, and some form of waterwheel -- can be seen throughout the countryside. Traditional hydropower installations are used to provide mechanical power to perform various tasks, such as driving millstones or rudimentary lift-irrigation pumps. In these areas, modern turbine installations are being readily accepted and numerous new productive end-uses for shaft power are easily discovered as the needs arise. However, consumers in these countries are less quick to make effective use of electricity, partly for cultural reasons such as an unwillingness to use electric appliances. For this reason, care should be taken to educate consumers in a newly electrified area to concepts such as energy rates, electricity uses, and the importance of maintenance. Incentives, such as providing favorable credit terms and tax breaks, should also be considered to encourage consumers to invest in productive uses of electric power.

[1]. The ranges provided are for information purposes only, since wide variations in these estimates for any particular site are the rule rather than the exception.

ANNEX C. METHODOLOGY FOR RANKING COUNTRY POTENTIAL

Several factors affect the ability of a country to successfully implement a decentralized hydropower program. First, the country must have the physical potential -- the topography must be suitable and the year-round streamflows adequate in areas near load centers. Second, there must be a demand for energy. Third, the country must have a good investment climate. Finally, financing must be available, either locally or through donor support, including AID missions.

To select priority countries, three factors -- physical resource potential, investment climate, and energy need -- were used. Because a country must first have the physical potential for generating hydropower, AID-assisted countries were ranked on the basis of decentralized hydropower potential. Then, those countries with physical potential were ranked in terms of the other two criteria--investment climate and energy need (see Figure 2 in Chapter III).

PHYSICAL RESOURCE POTENTIAL

Quantifying the physical decentralized hydropower potential in AID-assisted countries is not a straightforward task. Although data are available for total estimated hydropower potential in these countries, there have been no studies of decentralized hydropower potential. To determine those countries in which AID should focus its decentralized hydropower efforts, two approaches were employed.

APPROACH 1

This approach assumed that a country's decentralized hydropower potential was proportional to its entire hydropower potential. To eliminate the bias stemming from country size, a country's hydropower potential density (kW•km2) was used, as tabulated by the World Bank (41). Using this approach, 37 AID-assisted countries were identified as having good decentralized hydropower potential (See Table C1).

APPROACH 2

The second approach assessed the suitability of decentralized hydropower based on the following factors: averaage runoff, seasonal distribution of

Table C1. AID Countries with Significant Decentralized Hydropower Potential (41)

West Africa	East Africa	Asia and the Pacific	Latin America	Near East
Cameroon	Burundi	Fiji	Bolivia	Morocco
Congo	Kenya	India	Costa Rica	
Guinea	Lesotho	Indonesia	Dominica	
Liberia	Madagascar	Nepal	Dominican Republic	
Sierra Leone	Malawi	Pakistan	Ecuador	
Togo	Rwanda	Papua New Guinea	Guatemala	
Zaire	Swaziland	Philippines	Haiti	
	Tanzania	Sri Lanka	Honduras	
	Zimbabwe	Thailand	Jamaica	
			Panama	
			Peru	

runoff, and suitable topography. The reason for selecting each criterion is described below:

- The average runoff in a country gauges the volume of rainwater that finds its way into the country's smaller streams and rivers. The water found in major rivers originating in neighboring countries -- which is generally not tapped by decentralized hydropower plants -- is usually not reflected in the runoff.

- The seasonal distribution of runoff is important because decentralized hydropower plants generally do not rely on dams storing large volumes of water. Consequently, for power generation, rainfall must be evenly distributed year-round, not restricted to a few months each year.

- A suitable topography is needed because decentralized hydropower frequently relies on the contour of the land, and not a dam, to provide the necessary head for power generation. Consequently, the percentage of land topographically suited to hydropower generation is an important factor. A country with hilly or mountainous features is favored over a generally flat country.

For this approach, values from 1 to 5 for each of the three criteria were assigned to all the countries for which data was available. All the countries with a rating above 1 are ranked in Table C2 in order of their physical and hydrologic potential.

CONCLUSION

The countries selected using the first approach coincide fairly closely with the countries selected using the second approach. However, some of the limitations encountered in estimating decentralized hydropower potential using these approaches are readily apparent. Egypt, for example, could have been included as one of the AID-assisted countries having sufficient physical potential using the first approach, since the presence of a major river, the Nile, gives it a relatively high hydropower potential density. However, the waters of the Nile originate largely outside the country, with little small-hydropower potential found along the lower reaches of the river, other than some potential at irrigation canal drops. For Egypt, the second approach seems to give a more accurate measure of potential. Because the country has low rainfall and runoff, a long dry period, and few mountains--all factors that imply a negligible decentralized hydropower potential according to the second approach--it is

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Table C2. Index of Physical and Hydrologic Potential for Decentralized Hydropower for AID Countries Ranked the Highest by Approach 2

R[a]	M[b]	L[c]	P[d]	Country
5	4	5	100	Papua New Guinea
4	5	4	80	Indonesia
4	4	5	80	Costa Rica
3	5	5	75	Ecuador
4	4	4	64	Philippines
3	4	5	60	Guatemala
3	4	5	60	Panama
3	4	5	60	El Salvador
5	3	3	45	Liberia
3	3	5	45	Nepal
2	4	5	40	Honduras
2	5	4	40	Zaire
3	3	4	36	Guinea
3	4	3	36	Sri Lanka
2	4	4	32	Portugal
5	3	2	30	Sierra Leone
2	3	5	30	Peru
2	3	5	30	Madagascar
2	3	5	30	Dominican Republic
2	3	5	30	Haiti
2	3	4	24	Suriname
2	3	4	24	Bolivia
2	3	4	24	Jamaica
1	5	4	20	Tanzania
1	5	4	20	Kenya
1	5	4	20	Uganda
2	3	3	18	Cameroon
2	3	3	18	Congo
2	3	3	18	Thailand
3	3	2	18	Guyana
1	4	4	16	Rwanda
1	4	4	16	Burundi
2	2	4	16	India
1	3	5	15	Malawi
1	3	5	15	Lesotho
3	4	1	12	Fiji
1	3	4	12	Zambia
1	3	4	12	Zimbabwe
1	3	4	12	Morocco
1	2	5	10	Swaziland
1	4	2	8	Sudan
1	4	2	8	Tunisia
1	2	4	8	Togo
4	2	1	8	Bangladesh
1	3	2	6	Ghana
1	2	3	6	Pakistan
1	2	2	4	Somalia
1	2	2	4	Benin
1	3	1	3	Algeria
1	3	1	3	Mali
1	3	1	3	Niger

[a]Runoff: 0 mm to 250 mm = 1, 250 mm to 750 mm = 2, 750 mm to 1500 mm = 3, 1500 mm to 2500 mm = 4, above 2500 mm = 5.
[b]Months with less than 5% annual runoff: 0 months to 2 months = 5, 2 months to 4 months = 4, 4 months to 6 months = 3, 6 months to 8 months = 4, 8 months to 12 months = 1.
[c]Percent of land topographically suitable for decentralized hydropower: 0% to 20% = 1, 20% to 40% = 2, 40% to 60% = 3, 60% to 80% = 4, 80% to 100% = 5.
[d]Product of country-specific criteria rankings (R, M, and L).

Similarly, one reason for Pakistan's high ranking using the first approach is the presence of a large river, the Indus, as was the case with Egypt. However, this factor masks the absence of actual decentralized hydropower potential in a large part of the country. The second approach lists Pakistan fairly low on the scale, but this too is misleading, because the potential is averaged over the entire country. While the hydrology and topography over most of Pakistan are not favorable for decentralized hydropower generation, this is not the case in all regions. The North West Frontier Province, for example, has significant precipitation and the Himalayan terrain results in significant drops in elevation. The first approach erroneously indicates favorable countrywide potential and the second approach erroneously implies that there is low potential throughout the country. Yet, the northern mountainous portions of the country have significant potential that is already beginning to be exploited. Furthermore, the North West Frontier Province is an attractive area for decentralized hydropower activities because of its remoteness.

INVESTMENT CLIMATE

A means of measuring the criteria used in the second factor, investment climate, is the most difficult to determine. There are few tangible indicators of aspects such as donor interest, institutional capability, and policy environment that can be converted to numerical values. Nonetheless, a relative ranking of candidate countries is possible. For such a ranking, each country was rated subjectively on a scale of 1 to 3 for the following criteria: AID Mission support potential; the attitude of the national government toward decentralized hydropower; level of interest shown by various capital funding institutions, such as development banks, in support of decentralized hydropower; and the general in-country capacities for effective project design and management. The resultant country ranking by investment climate is shown in Table C3.

ENERGY NEED

Much of the world's hydropower potential exists in areas where there may be a need but no market or ability to pay for the energy generated. Although markets will develop in these areas over time, it is important to concentrate on areas where energy need and electricity demands exist or will soon develop. These areas may be assumed to be in countries with a high growth rate for electricity demand and thus a need for additional generating sources. These countries will also need hydropower to displace higher-cost energy supplies. Countries with high energy costs usually depend on imported oil and generate much of their electricity from oil. For the purpose of ranking the AID-assisted countries, energy need

ble C3. Ranking of Countries in Table C1 According to Investment Climate and Energy Need Criteria

	Investment climate					Energy need				
	1[a]	2[b]	3[c]	4[d]	5[e]	6[f]	7[g]	8[h]	9[i]	10[j]
rica										
ongo	2	3	3	1	9	10	67	16	18	85
uinea	2	2	3	1	8	7	46	11	12	58
ierra Leone	3	2	1	1	7	5	33	17	19	52
iberia	2	3	2	2	9	3	20	3	3	23
ogo	3	3	3	2	11	10	67	0	0	67
ameroon	1	2	2	1	6	7	47	2	2	49
aire	3	3	2	1	9	1	7	2	2	9
adagascar	3	3	3	2	11	7	47	14	15	62
urundi	1	3	2	1	7	10	67	4	5	72
alawi	1	1	2	1	5	9	60	25	28	88
enya	1	1	1	2	5	7	47	4	5	52
wanda	1	3	3	1	8	10	67	6	7	74
anzania	1	2	1	1	5	5	33	2	2	35
imbabwe	2	2	1	2	7	7	47	0	0	47
waziland	1	2	2	3	8	4	27	1	1	28
esotho	1	2	3	1	7	3	20	14	15	35
tin America										
onduras	2	2	2	3	9	10	67	3	3	70
ominican Republic	3	3	3	2	11	7	47	9	10	57
uatemala	3	3	3	2	11	12	80	4	5	85
uador	3	3	2	3	11	10	67	11	12	79
Costa Rica	3	1	1	3	8	6	40	1	1	41
Jamaica	1	2	2	1	6	3	20	90	100	120
Bolivia	2	3	1	2	8	8	53	3	3	56
Peru	3	3	2	2	6	7	47	12	13	60
Panama	1	2	3	2	8	5	33	8	9	42
Haiti	1	2	1	1	5	11	73	28	32	95
Dominica	2	3	2	1	8	5	33	6	7	40
Middle East										
Morocco	3	3	3	2	11	9	60	25	28	88
Asia and the Pacific										
Nepal	1	3	3	3	10	12	80	2	2	82
Papua New Guinea	2	3	2	1	8	3	20	46	53	73
Philippines	1	2	1	3	7	8	53	15	17	70
Thailand	3	3	3	3	12	8	53	11	12	65
Sri Lanka	1	3	3	2	9	9	60	14	15	75
Indonesia	2	3	3	3	11	15	100	21	23	123
India	2	3	3	3	11	7	47	1	1	48
Fiji	2	3	3	2	10	7	46	10	12	58
Pakistan	1	1	2	2	6	8	53	0	0	53

emonstrated AID Mission interest, based on NRECA experience, rated on a scale of 1 to 3; if unknown, value of 1 is given.
emonstrated national government support, based on NRECA experience, rated on a scale of 1 to 3; if unknown, value of 1 is given.
emonstrated donor/lender interest, based on NRECA experience, rated on a scale of 1 to 3; if unknown, value of 1 is given.
emonstrated institutional capacity, based on NRECA experience, rated on a scale of 1 to 3; higher value given where private-sector potential
ists.
ombined "investment-climate" value, derived by adding values from columns 1 to 4.
rojected 1985 to 1990 average annual electricity-demand growth (%).
olumn 6 value divided by 15 to normalize data (%).
stimated 1990 percentage of total electricity generation from petroleum.
olumn 8 value divided by 90 to normalize data (%).
ombined "energy-needs" value derived by adding values from columns 7 and 9.

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C.c

was based on the projected growth rate of annual electricity demand for 1985-1990 and the estimated percentage of electricity generation from petroleum sources in 1990. The ranking is shown in Table C3.