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COSTA RICA

A proposal for private sector development of small hydroelectric power systems

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Trip report

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Small Decentralized Hydropower (SDH) Program
International Programs Division

National Rural Electric Cooperative Association (NRECA)
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SUMMARY

Costa Rica is rich in hydroelectric power resources, but relies, for the most part, on foreign-source inputs to make use of them, including steel, turbine-generating equipment, and to a lesser degree, engineering expertise. This foreign dependency is not uncommon in developing countries, but having a highly educated and enterprising populace which enjoys a largely open, free-market economic system, Costa Rica could relatively easily convert at least part of its dependency on imported energy technology to local-based development.

What makes it attractive for Costa Rica to do so is its enormous foreign debt problem and its large and growing need for electricity. Already facing a foreign borrowing level which could potentially reach $U.S. 9 billion by the end of the decade, Costa Rica likely will need to borrow over $U.S. 1 billion in additional foreign currency to meet the new power capacity requirements of the next two or three decades. This report considers one means of reducing this foreign debt requirement, a private sector approach to small decentralized hydropower development based on local manufacturing and engineering of small hydro equipment and systems.

The basic economic assumption of this approach is that small, local-design hydro systems, having a total foreign import component of 20% of capital cost, could economically compete with large hydro schemes having a foreign exchange cost exceeding 70% of investment, despite the fact that economies of scale favor larger schemes. Moreover, hydroelectric development implemented on a decentralized basis implies potentially greater efficiencies in system development and management, reduced transmission costs, local employment creation, minimal environmental and health hazards, and more effective utilization of invested resources.

The envisioned program for local-design development of small hydro plants (up to 1 MW) interconnected with the grid includes:

- the establishment of one or more commercial small hydro enterprises with a U.S. partner to fabricate and assemble small hydro turbine-generating equipment up to 500 kW, and provide a range of engineering, general contracting, and training services to project developers; and

- the implementation of projects by independent producers, including rural electric cooperatives, municipal utilities, and possibly, private developers, under a national institutional framework to promote and regulate small hydro development.

It is proposed that NRECA conduct a general feasibility assessment under the S&T/EY Small Decentralized Hydropower Program to examine the energy, economic, and institutional policy ramifications of such a program, technical considerations regarding hydrologic and site potential and standard design parameters for implementing a large number of projects, and the potential for a private sector initiative as described. This could be undertaken as part of an on-going effort by NRECA at the request of AID/San Jose to assess the general feasibility of expanding the decentralization of Costa Rica's rural electric system through the creation of new cooperatives.

BACKGROUND

Purpose of trip

The principal purpose for my being in Costa Rica was to attend a regional workshop on the Productive Use of Rural Electricity in early December 1983, funded by AID through a grant to NRECA and cosponsored by the Instituto Costarricense de Electricidad (ICE), the Servicio Nacional de Electricidad (SNE), and the rural electric cooperatives of Costa Rica. During the week I was approached by Gonzalo Monge, Vice President of Coopelesca electric cooperative, who asked if I would be available to look at some small hydro sites the Cooperative was interested in developing. One was a 55 MW plant, primarily as part of an ammonium fertilizer venture. I was also contacted by Roberto Arce, an engineer with Junta Administrativa de Servicios Electricos de Cartago (JASEC), a municipal utility system in Cartago, with a similar request.

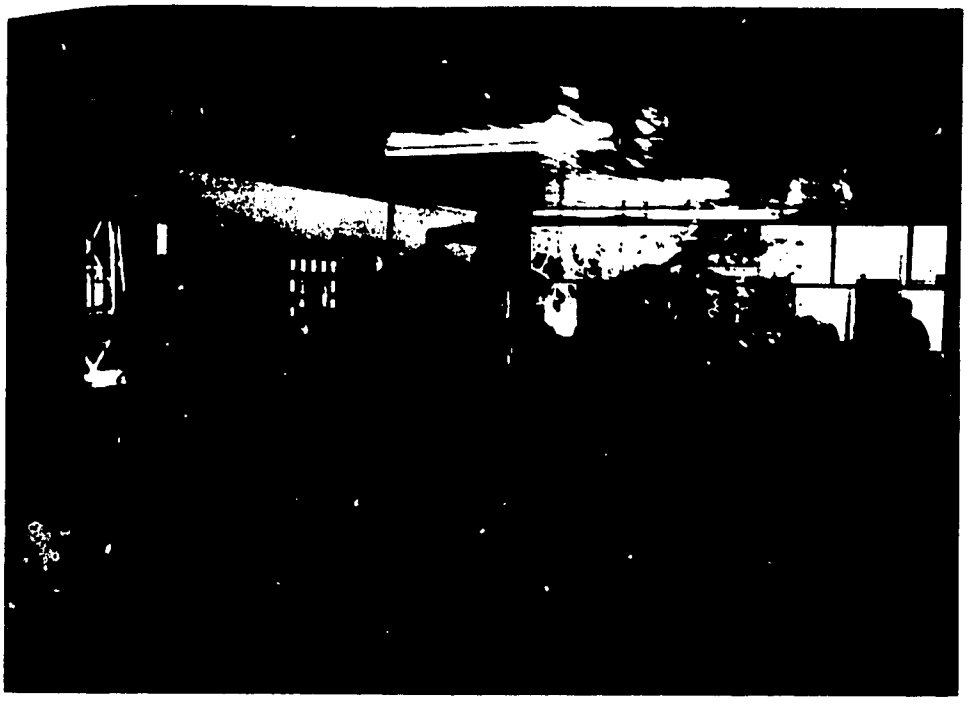
Based on these two requests, I sought and received concurrence from the AID Mission to spend a few extra days in Costa Rica for the purpose of visiting these sites. I also informed the Mission of an on-going study of potential markets for commercial joint-venture enterprises to manufacture small hydro equipment and systems, which the SDH Program is carrying out at the request of AID's Bureau for Private Enterprise (PRE). Costa Rica had been listed as one of the target countries for PRE-supported ventures, and coincidentally was identified by the SDH Program as a prime candidate for a possible small hydro venture between a U.S. firm and a local partner. I suggested to the Mission that this would be a good opportunity to explore general conditions and local interest for such a venture.

Prior to departing Costa Rica, I visited the AID offices to brief Heriberto Rodriguez, Chief of the Engineering Department, on the results of my trip and promised to send a copy of this report, outlining recommended steps to promote the undertaking of small hydropower development in Costa Rica.

Summary of activities

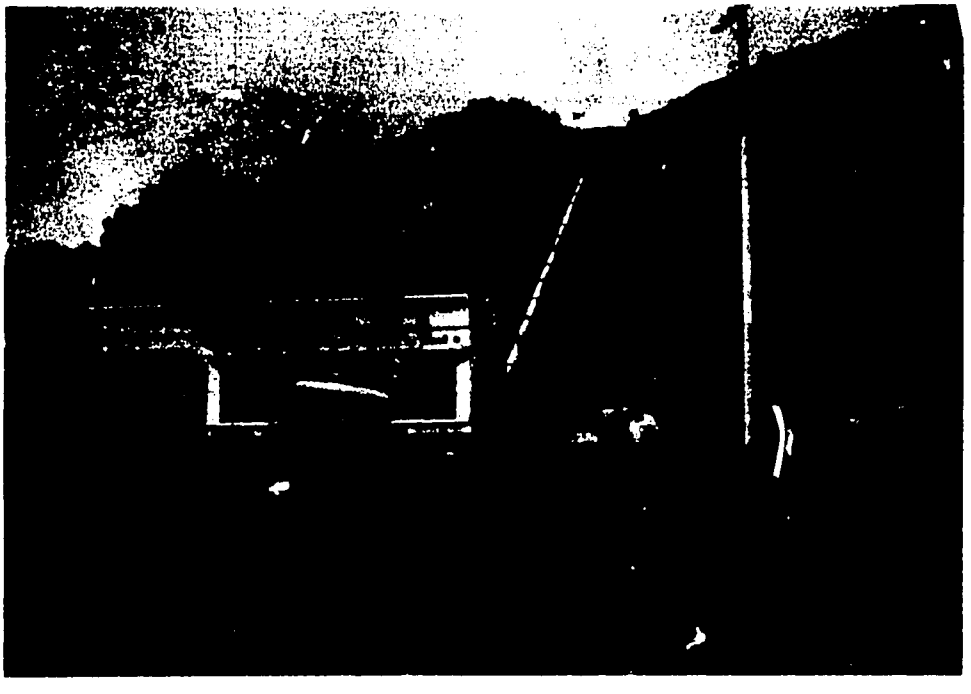
During my stay in Costa Rica, I visited 5 different small hydropower sites, consisting of 12 turbine-generators totalling 12 MW of installed capacity.

Textiles e Cordiles Corporation. On Thursday the Productive Uses workshop suspended its working sessions to take a field trip in the service area of Coopesantos rural electric cooperative, south of San Jose. The first stop on this trip was a manufacturing complex at La Lucha which had three plants producing hemp rope, synthetic bags and containers, and wood furniture and products. The total load requirements of the complex was roughly 900 kW, served primarily by a 14.4 kV line from the coop. Part of the load, however, was served by a 450 kW hydropower plant located in the center of the complex. The station is owned and operated by the corporation, and consisted of three Pelton machines (2 x 175 kW; 1 x 100 kW) operating with a head of about 100 m. The plant was loaded at 160 kW at the time of our visit, with one of the units out of service for maintenance.



Three Pelton units operating at the Textiles e Cordiles manufacturing complex in La Lucha (commissioned in 1952).

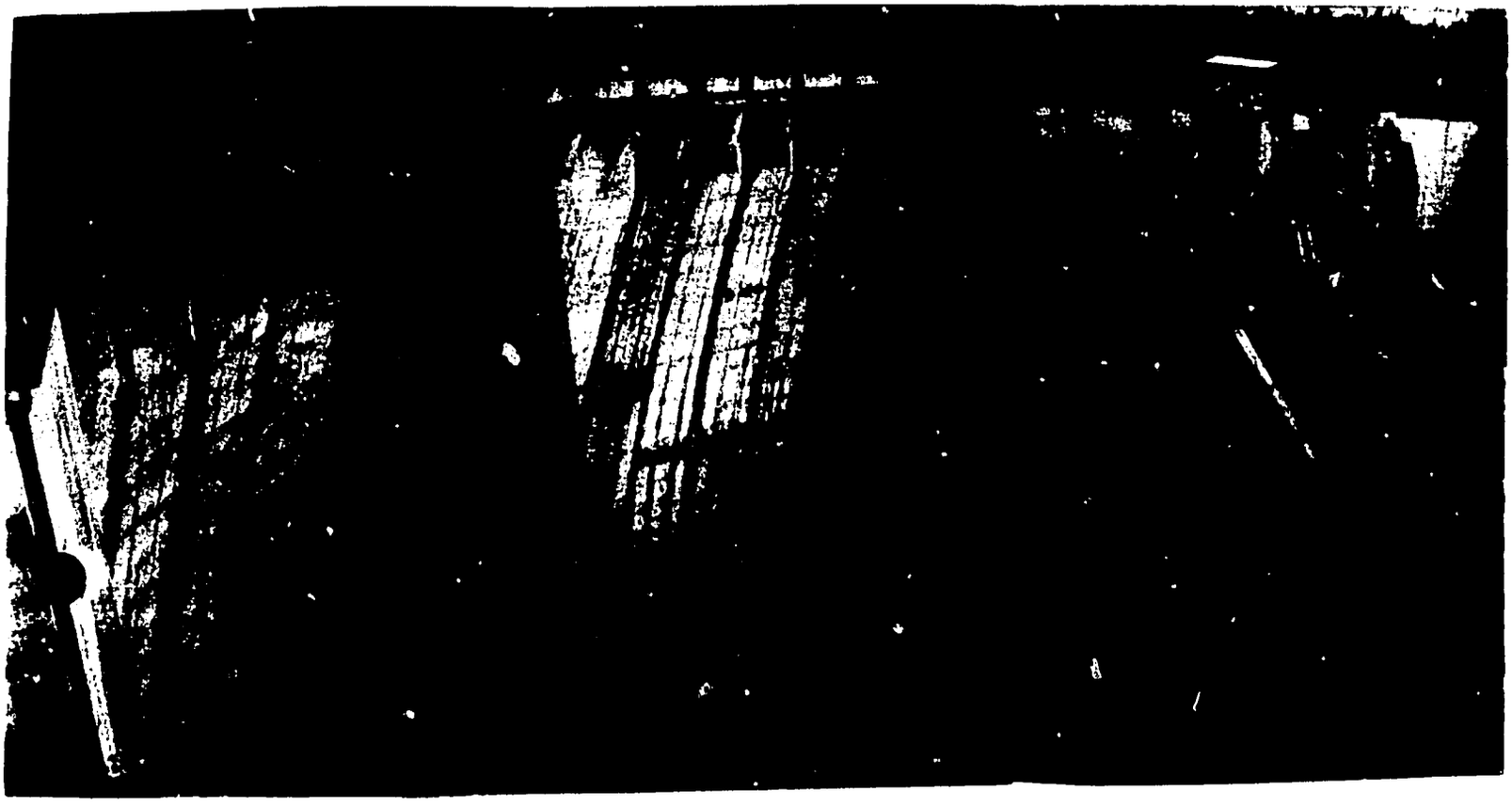
JASEC. On Friday after the close of the workshop, I traveled to the Cartago region with Roberto Arce to visit the JASEC hydro facility. The utility purchases the bulk of its electricity from ICE, supplemented by a series of 3 small hydro installations located on the Birris River several km east of Cartago. The plants are owned and operated by JASEC, totalling 8.5 MW (1 x 4,500 kW; 1 x 2,500 kW; 1 x 1,500 kW). The total peak load for the JASEC system is currently about 25 MW. JASEC is interested in developing other sites in the immediate vicinity, including a 300 kW restoration



Powerhouse for JASEC's 4.5 MW plant on the Birris River.

project and a 16 MW site on the lower reaches of the Birris River. Roberto was enthusiastic about fabricating small turbines, possibly at a JASEC service workshop adjacent to the 4.5 MW powerhouse. He is specifically interested in making a crossflow turbine for the 300 kW site, but is also interested in starting up a commercial venture to market small units throughout the country, in cooperation with a U.S. small hydro firm.

Before leaving the Cartago area we stopped to look at a high arch dam (Cachi Reservoir) for a 100 MW plant on the Macho River several km from the Birris River site. This is one of several large hydro plants serving the country's national grid system.



High arch dam holding back the waters of the Cachi Reservoir.

Coopelesca. On Monday I drove to Quesada with Carlos Chavez, Chief Engineer of Coopelesca electric cooperative, to inspect sites in the Coopelesca service area. En route we stopped at a small hydro site north of Laguna, located in the service area of Coopealfaroruiz electric cooperative. This site is one of a number of small plants implemented in the region by private entrepreneurs in the 1950's. Most of these consist of a concrete diversion weir, a lengthy concrete-lined headrace canal following the contour of the hillside, leading to a concrete forebay. Steel penstocks carry the water down steep grades (20-100 m head) to either Francis or Pelton turbines. This particular site had a 100 kW Pelton unit operating with a head of 90 m. A 600 kW Francis unit was removed from the site when the owner sold the plant to a group of four families nearby several years ago (for a reported price of $4,500). The current owners use the plant for their homes; it was loaded at about 12 kW at the time of our visit. With potentially 680 kW of developable capacity at the site going unused, it would appear to be a good opportunity for the local cooperative to tie in a very inexpensive source of power to its system, but we did not pursue the issue.

Concrete weir and intake for the 700 kW plant near Laguna.

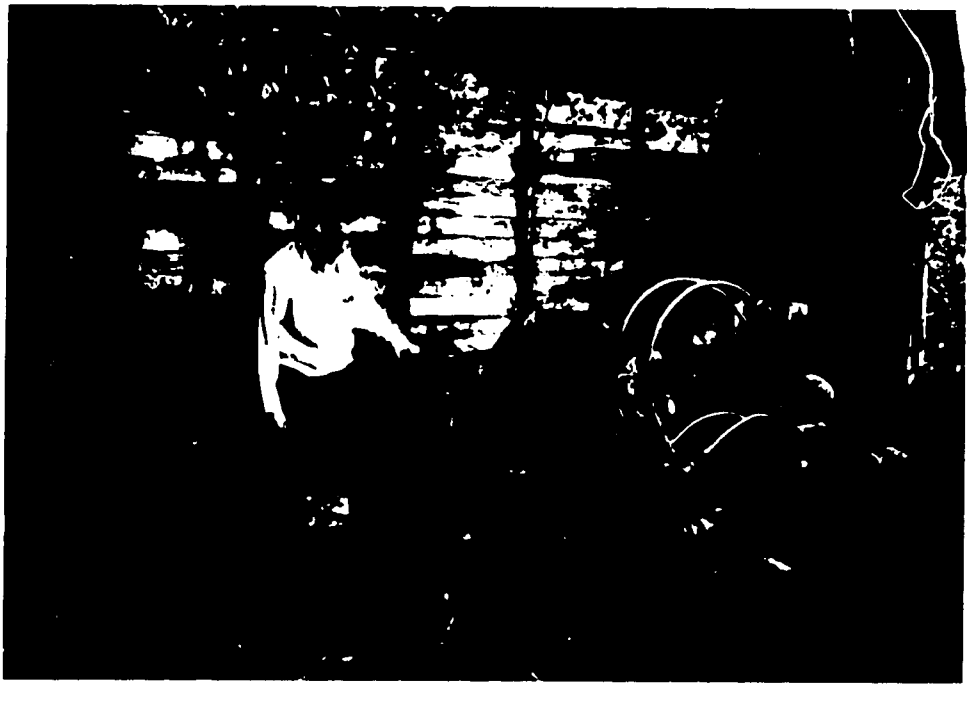
At Ouesada, where the cooperative's headquarters are located, we visited a series of hydro installations owned and operated by a private power company, Matamoros Empressa Electrica, on the Platanar River just north of the town. Matamoros used to operate as a utility in the town, but recently folded its retail operation and presently sells power at wholesale rates to the Cooperative. The plants, built around 1958, consist

Concrete-lined headrace leading to one of the Matamoros plants near Quesada.

of 4 Francis units (3 powerhouses) totalling nearly 3 MW. The total peak load of the cooperative is currently about 8 MW. The general layout of all 3 plants is similar to the scheme we saw earlier, and are arranged in a cascading pattern down roughly a 3-km stretch of the river. Coopelesca in interested in adding a fourth stage to the scheme lower down on the river which would provide up to 10 MW operating with a head of some 250 m. A headrace canal of some 4 km would be required, with a penstock exceeding 1 km.

At the Coop offices, Carlos Chavez briefly showed me the feasibility report and several drawings for the 55 MW plant. Its primary function would be to provide off-peak power to a bank of electrolyzers located adjacent to an ammonium fertilizer plant on the West Coast. The power would be wheeled over the Continental Divide on ICE lines to the fertilizer production site. There the power would be used to produce, through an electrolytic process designed by Norsk Hydro (Norwegian), ammonium nitrate from air and water. The West German government provided a grant to fund the feasibility study, which was performed by an engineering firm in San Jose. Coopelesca is seeking financing for the plant, roughly $45 million, possibly from the Germans or Norwegians, who would supply the equipment. An important economic aspect of the plant, which is as yet uncertain, is the planned sale of 40 MW to ICE during peak demand periods.

The last site I visited was an abandoned micro-hydro plant located about 15 km east of Quesada. It had a penstock of about 100 m length leading from a forebay down a gradual slope parallel to a small creek, with a 90-degree turn toward the creek down a steep incline to a woodframe powerhouse. The latter was in very poor condition, but the small Francis turbine within it appeared to be in good condition. The generator and governor were missing. This was one of the many abandoned sites in the Coopelesca service area mentioned to me by Carlos, and was owned by a dairy farmer now being served by the grid. Carlos indicated that most of these plants were abandoned after very cheap, subsidized grid power became available.



Powerhouse and turbine of abandoned micro-hydro site east of Quesada.

FINDINGS

Costa Rica exhibits excellent conditions for small decentralized hydropower development: mountainous terrain (high head), year-round rainfall and streamflows, and a plethora of small streams and rivers ideal for small-scale installations. The country is estimated to have a developable potential of 40 billion kWh of hydro energy, far and away the greatest of any of the Central America countries. Yet only half of one percent of this potential has been tapped. The installed capacity, counting all means of generation, is 785 MW, including hydropower plants of 30, 100, 120, 153, and 175 MW. Small hydropower (under 5 MW) contributes less than 5% of this total. Small hydro has not been emphasized since economies-of-scale tend to favor larger plants, and since ICE, which is the primary supplier of electrical energy in the country, prefers large, centralized generating stations.[1] A number of potential sites for large hydro installations still exist, and it is the general view of ICE that these potential sources will supply the bulk of Costa Rica's future electrical energy requirements. Construction is currently underway to expand two existing large hydro installations by a total of 330 MW, and plans exist for development of other plants, including one said to be 1,200 MW.

Since 1972, consumption of electricity has more than doubled, despite a sharp economic decline in recent years. This decline, marked by a drop in real GDP of -15% between 1977 and 1983, suggests a moderation in demand for electricity, although both Coopelesca and JASEC are experiencing growth rates of between 5-10% annually within their systems. ICE figures show that for 1980-81, peak demand on its total system increased by roughly 50 MW. Between 1972-82, peak capacity requirements rose at a steady rate from 220 MW to 420 MW, or about 20 MW annually.

While Costa Rica's uncertain economic future makes it difficult to predict long-term electricity demand growth rates, in the context of planning periods generally used for the power sector (25-50 years in the case of power plants), there will undoubtedly be substantial requirements for additional power generation facilities during this period. Based on an annual capacity requirement increase of 20 MW, total installed capacity should exceed 1,000 MW by the year 2000 and 1,700 MW in 50 years. On the other hand, if electricity demand continues to double every ten years (as ICE optimistically projects), the capacity growth requirements would be much higher.

Owing to Costa Rica's immense hydroelectric potential, hydropower likely will constitute a major portion of this supply. The issue addressed here is what role, if any, small hydro facilities may play. Since choices made today in selecting the means of new generating facilities will carry economic consequences for generations to come, these choices deserve careful study.

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[1] Apart from the economies-of-scale argument, it is commonly found that national parastatal utilities prefer large-scale hydro facilities to smaller-scale plants since they are more conducive to centralized administration and management and, by permitting investment costs to be lumped under a single project, appear more attractive to financial institutions than many scattered projects. The last small hydro plant built in Costa Rica was commissioned in 1968.

The case for small hydropower

Most critiques of Costa Rica's present economic crisis -- including AID's 1985 Annual Budget Submission for Costa Rica — point to a severe trade imbalance in recent years as a fundamental obstacle to Costa Rica's escape from its current predicament. Costa Rica's present foreign debt is about $U.S. 4 billion, yielding a current debt/GDP ratio of 140%. The debt service requirement alone is tremendous, equalling 50% of 1983 exports. This situation is not likely to see much improvement in the foreseeable future.[2] Policies designed to reverse the adverse foreign trade trend are therefore appealing. One sector, with this objective in mind, is the power sector. Capital requirements in this sector are likely to be as great or greater than any other area of public investment. In the U.S., for example, it is estimated that some 30% of all public and private investment goes into this sector. A figure which has been quoted for developing countries is 20% of total capital investment. For Costa Rica, much of this investment will go to the construction of hydropower plants and the attendant transmission costs.

Hydropower projects to serve national energy needs may be divided into three categories: large hydropower plants, conventional small hydro plants, and local-design small hydro plants. While there are a number of distinguishing features which define these as separate catagories, the feature most relevant to the present discussion is the degree to which foreign exchange is necessary in constructing each type of project.

Table 1. Typical foreign currency requirements for a large hydropower project

Item	Percent of project cost	Percent foreign currency required	Foreign currency as percent of total
General	2.0	50.0	1.00
Site mobilization	3.0	60.0	1.80
Dam and intake	29.0	50.0	14.50
Powerhouse	4.0	50.0	2.00
Turbine-generator	24.0	95.0	22.80
Transmission	5.0	75.0	3.75
Contingencies	4.0	75.0	3.00
Engineering	10.0	85.0	8.50
Const.-period interest	19.0	75.0	14.25
Total	100.00		71.60

[2]The implications of economic recovery for Costa Rica's foreign debt position are underscored by the Kissinger Commission's claim that over $5 billion in additional external financing would be required during the balance of this decade merely to return to pre-1980 economic conditions.

Large hydro

The principal components of a large hydropower project are a large dam, a powerhouse, and the turbine-generating equipment. In most developing countries, these and other components are all engineered by international consultants, and constructed by international contractors. They are often financed by multilateral institutions and generally require over 70% of the financing to be in foreign currency. Table 1 shows the typical currency requirements for large hydro plants.

Generally, the unit capital cost of large hydropower schemes is lower than the cost of small hydro schemes, due to economies-of-scale. Moreover, some of the cost of a large dam can be charged to other sectors for benefits such as flood control, irrigation, or water supply. Typically, costs will run from $U.S. 800-2,000 per installed kW, which includes the cost of the transmission link to the national grid.

Conventional small hydro

Fig. 1 shows a typical configuration of a small hydro plant and the major structural components. Standard designs are available for each of these components that utilize capital-intensive construction materials and techniques (detailed designs, reinforced concrete, steel penstocks, bulldozers, and highly skilled contractors). These will be referred to as conventional designs. All of the small hydro installations visited during this trip were of this design type.

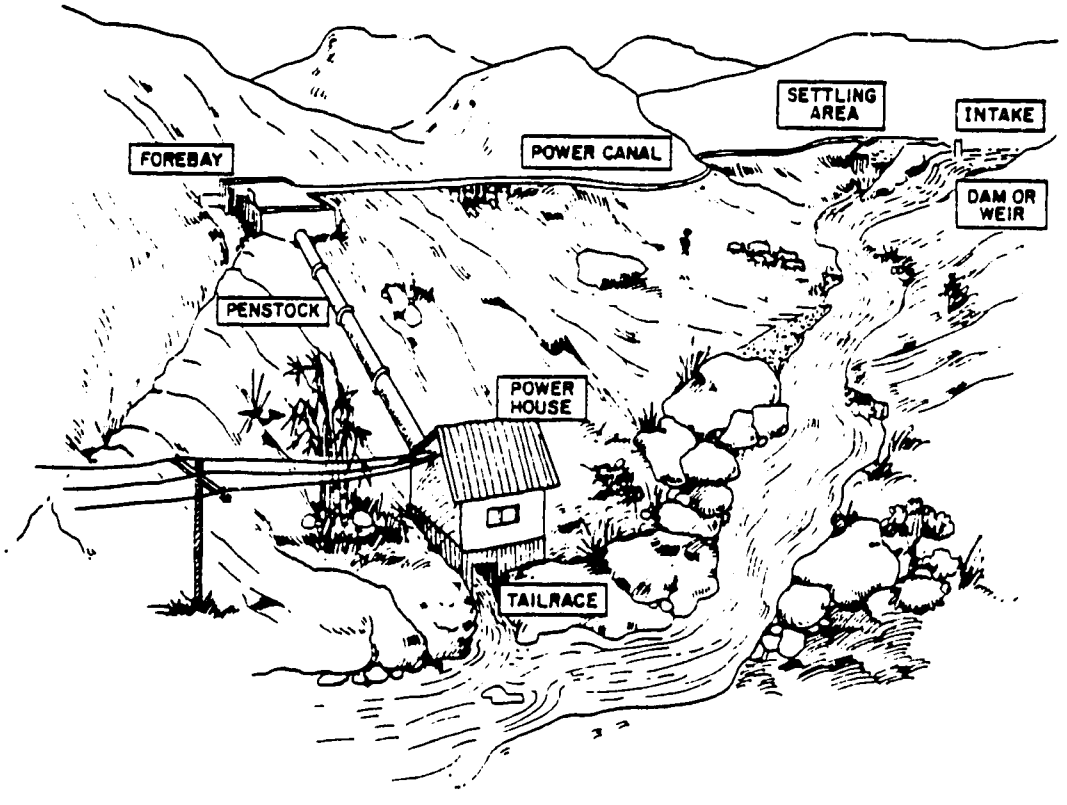

Fig. 1. Typical configuration of a small hydropower plant

For a conventional small hydro project the typical requirements for foreign currency are shown in Table 2.

Table 2. Typical foreign currency requirements for a conventional small hydro project

Item	Percent of project cost	Percent foreign currency required	Foreign currency as percent of total
General	2.0	0.0	0.0
Site mobilization	10.0	22.0	2.20
Weir and intake	6.0	36.0	2.16
Penstock and canal	24.0	45.0	10.80
Powerhouse	4.0	31.0	1.24
Turbine-generator	20.0	80.0	16.00
Distribution	11.0	50.0	5.50
Contingencies	9.0	25.0	2.25
Engineering	7.0	75.0	5.25
Constr.-period interest	7.0	50.0	3.50
Total	100.00		48.90

The unit capital costs of this approach to hydropower development typically run from $ U.S. 1,500-3,000/kW.

Local-design small hydro

For each of the components shown in Fig.1 there is usually an alternative design which maximizes the use of locally available materials and more labor-intensive construction techniques, thereby minimizing the foreign currency requirements. These alternative designs, applicable for hydropower plants under 1,000 kW, still require careful design and construction management, but yet are simple enough that local engineers and contractors can properly implement projects. Some of alternative designs possible in Costa Rica are discussed below.

Weir. Rather than a large dam to store massive amounts of water, small hydro units usually entail low weirs with limited storage capabilities. These weirs can be constructed as "gravity structures" meaning that their stability is dependent upon their weight and not so much their foundation anchoring and material strength. Such designs are simple compared to reinforced concrete structures and can use local masonry or gabion construction. They do not need to be watertight, but simply function to divert water toward the intake structure.

Intake structure. Conventional designs call for mechanical gates and automatic controls at the water intake. Alternative designs would use wood stop logs in lieu of metal gates, and depend upon an intake spillway to control the water level and spill excess flow caused by system surges.

Canal. Conventional designs usually call for headraces of low pressure steel penstock. In most instances a canal can be used in lieu of a low pressure penstock, and in a few instances, soils conditions will allow them to unlined. Canals can be hand-dug and lined with a variety of materials, depending upon soil conditions. If structural strength is required then wood or tapered masonry construction can be used in lieu of reinforced concrete. If strength is not a concern, but seepage of water is, then thin impervious liners can be layed in the canal.

Penstock. As shown in Table 2, steel penstock is a major foreign currency component of conventional small hydro projects. However, it is technically feasible (and was common practice in the 1800's) to construct medium presure penstocks out of wood stave pipe, thereby reducing the foreign currency requirements where wood resources and skilled labor is available.

Powerhouse. Hydroelectric powerhouses require substantial foundations to allow proper support of equipment and to absorb hydro dynamic forces. However, the local, common construction materials such as wood may be used for the superstructures instead of concrete.

Turbine-generating equipment. To ensure system reliablilty and life, proven designs should be used for all the mechanical and electrical equipment. However, if a national commitment is made to small-hydro development then it would reasonable to promote a local manufacturing capability in Costa Rica, under license or joint-venture with a reputable manufacturer.

Distribution. Although it currently imports wood poles from Honduras, Costa Rica has good timber resources and it is NRECA's recommendation that it grow and process its own wood poles. Contractors in Costa Rica are capable of installing distribution lines.

Contingencies. Since these projects are implemented primarily by local agencies and firms, contingency cost are generally limited to local currency cost.

Engineering. The local-design option engineering cost can be lower than the conventional option if a firm national commitment is made to train local engineers, operators, contractors, and develop manufacturing capabilities. These "institution-building" requirements can, themselves, entail a cost, but they are rapidly defrayed when applied to a large number of projects. Moreover, the bulk of this cost would be transferred to the local currency column, compared with the conventional option. In the context of NRECA's recommended approach, the training costs would be met largely through a private joint-venture involving one or more U.S. small hydro firms.

Construction-period interest. It is interesting to compare the amount of foreign currency used to pay interest charges during contruction of a large project, Table 1, and the requirements for the small hydro scheme shown in Table 3. This difference is due to both the lower amount of foreign currency required for the latter, and a shorter construction period.

For a local-design small hydro option the typical requirements for foreign currency are shown in Table 3.

Table 3. Typical foreign currency requirements for a local-design small hydro project

Item	Percent of project cost	Percent foreign currency required	Foreign currency as percent of total
General	2.0	0.0	0.0
Site mobilization	3.0	0.0	0.0
Weir and intake	5.0	15.0	0.75
Penstock and canal	25.0	20.0	5.00
Powerhouse	3.0	10.0	0.30
Turbine-generator	25.0	40.0	10.00
Distribution	13.0	20.0	2.60
Contingencies	9.0	0.0	0.0
Engineering	10.0	0.0	0.0
Constr.-period interest	5.0	20.0	1.00
Total	100.00		19.65

The unit capital costs of local-design plants are subject to many variables, depending on the degree to which alternative design options to the conventional approach are possible. In general, the costs for these plants fall within the range of US $1,000-2,500/kW, although the cost could go lower.

Economic considerations

From the foregoing discussion, typical unit capital costs and the respective foreign currency requirements of large and small (conventional and local-design) hydro plants may be summarized in tables 4 and 5.

Table 4. Average nominal costs of hydropower project construction

Plant Type	Typical cost per kW ($U.S.)	Mean cost per kW ($U.S.)
Large hydro	800 - 2,000	1,400
Conventional small hydro	1,500 - 3,000	2,250
Local-design small hydro	1,000 - 2,500	1,750

Table 4 shows that the costliest option is the conventional small hydro plant, and the least costly option is the large hydro plant, as expressed in nominal terms ($U.S.). Table 5, on the other hand, views these costs in economic terms, taking into account what may be seen as the true value of foreign exchange to Costa Rica.

Table 5. Economic cost of hydropower project construction

Plant Type	Percent of foreign currency	Economic cost per kW ($U.S.)
Large hydro	72.0	392 + 1,008 (1.5) = 1,904
Conventional small hydro	50.0	1,125 + 1,125 (1.5) = 2,800
Local-design small hydro	20.0	1,400 + 350 (1.5) = 1,925

It has been noted that a considerable value is attached to foreign exchange in Costa Rica, in view of the current foreign debt crisis. This value, for purposes of economic analysis, is generally reflected by applying a "shadow" foreign exchange rate to all project values involving foreign currency, if the official exchange rate set by the government in artificially low. If the official rate is economically valid, then the relative value of foreign exchange purchases is shown by comparing them with the local currency cost of comparable goods and services originating within the country. With the recent devaluation of the Colone following the intervention of the IMF, the offical exchange rate of 43 = $1.00 is close to the proper valuation. Since, for the sake of simplicity, all values are expressed here in terms of dollars, we will use a shadow rate equivalent to 150% of the nominal dollar cost applied to all purchases requiring foreign exchange.[3] The foreign currency requirements shown in Table 5 are therefore multiplied by 1.5 to reflect the economic costs of the three investment options. In these terms, then, Table 5 indicates that the local-design small hydro option becomes reasonably competitive with the large hydro option.

The essential assumption here is that each dollar equivalent of foreign currency that can be transferred to local currency cost is worth the equivalent of at least a 50% reduction in the per-dollar economic cost of building power plants in Costa Rica. While it is true that economies-of-scale are foregone in electing to substitute small plants for larger ones, such an analysis does not take into account other cost-influencing factors which further improve the economic competitiveness of smaller stations.

Opportunity cost of capital. Large hydro plants require up to 10-15 years to plan and construct. Small plants (under 1 MW) require no more than 2-4 years. The consequential tying-up of capital for longer periods of time bears a certain economic cost as well, depending on the discount rate used in assessing this cost. Moreover, on the benefit side of the equation, large plants frequently suffer more from capacity underutilization than small plants, meaning that the economic return on smaller investments--made in a pattern which follows more closely with power demand growth--is realized sooner and more fully.

[3]This is probably, if anything, a conservative estimate of the value Costa Rica attaches to foreign currency, considering that the present exchange rate reflects more than a 400% devaluation of the Colone against the dollar since 1981.

Transmission costs. The costs for large hydro plants in Table 1 include the cost of constructing a feeder line from the hydro station to the grid. What is not reflected in that table, but which soon will entail an enormous cost for Costa Rica, is the need to upgrade existing transmission and distribution facilities in order to transmit increasingly higher voltages from large central stations to the distribution centers many miles away. As electricity requirements grow, transmission voltages will have to be increased accordingly, meaning a cost of millions of dollars (largely in foreign currency). Alternatively, capacity could be added on a decentralized basis at locally-sited stations, delaying--and probably reducing--this cost considerably.

Operating costs. Centralized management of public utility systems in developing countries are typically characterized by excessive operating costs due to misuse of funds, overstaffing, and general inefficiency. ICE is said to have an annual operating deficit in the millions of Colones, very likely due, in part, to some of the conditions which usually plague large government-run utility systems, as well as large tariff subsidies. These costs are easily hidden in national budgets, but bear an economic cost to the country nevertheless. To the degree that the power supply system, together with the power distribution system, can be decentralized, many of these costs could be brought under control.

Environmental and health costs. It was noted earlier that large hydro schemes may provide secondary benefits in the form of improved water resource management capabilities. It should also be noted that impounding water behind large dams can result in damage to natural eco-systems which depend on the free flow of water in rivers and streams, and have been responsible for health hazards (schistosomiasis, malaria) in certain cases. The creation of reservoirs also removes land from alternative productive uses, and frequently necessitates the relocation of human settlements. The danger of dam failures to settlements downstream, moreover, is always present. The small hydro plants described above, on the other hand, are generally "run-of-river" schemes, which for the most part eliminate the risk of environmental or health hazards.

Other economic considerations. The economic ramifications of a local-design small hydro approach reflected in Table 5 are limited to a preliminary analysis of the benefits arising from foreign exchange savings. In a more complete economic appraisal, other considerations should be built in, such as, for example, its impacts on employment, income distribution, and national security. Certainly the employment implications of such a policy would have to be considered, since the local-design option emphasizes the mobilization of local (and possibly underutilized) resources. To the degree that such employment creation reduces unemployment, the economic cost of labor inputs could be lower than the wage costs which would appear in a purely financial analysis; that is, the "opportunity cost" of the labor could be quite low. In July 1982, the Inter-American Development Bank estimated that labor underutilization in Costa Rica represented 23.8% of the labor force. Since the other chief attributes of this approach involve decentralization and self-reliance, the distributional and national security (e.g. strengthening in-country technical capacities) benefits are inherent.

Conclusion

In view of the premium which has been placed on investment policies giving rise to earnings or net savings of foreign exchange, it is in Costa Rica's interest to explore every opportunity which could meet the overall objective of reducing future foreign debt. The question raised by this report is whether such an opportunity exists in Costa Rica's power sector by means of import substitution. Import substitution projects, as a general

approach to addressing foreign debt problems, have drawn wide criticism since in practice they often result from investment decisions which do not adequately take into account the economic principle of comparative advantage. They also tend to concentrate in manufacturing ventures to produce consumer goods aimed at more wealthy members of society. In this case, however, neither of these concerns is at issue. Electricity is something all Costa Ricans desire, and will continue to buy in growing quantities, whether based on imports or not. Moreover, the comparative advantages of producing electricity based on largely local-currency investments, as proposed here, appear to be valid.

This is not to suggest that small hydro installations could be sufficient to substitute large generating plants entirely, but rather that they could provide a substantial supplementary source of generation for Costa Rica. If the total generating capacity requirements of Costa Rica over the next 30 years indicate that an additional 600 MW of plant be added to the system, it would not be unrealistic to suppose that 200 MW of that could come from small hydro installations (roughly 15 plants a year averaging 500 kW). This translates to a foreign exchange savings of about $150 million during this period. It is conceivable that the small hydro contribution could be considerably higher, if an adequate national commitment to small hydro is made.[4] It is possible, for example, that the successful operation of one small hydro manufacturing enterprise could soon stimulate others to start up similar businesses, as has happened in Nepal.

The general approach to achieving this level of development, discussed in more detail in the following section, would emphasize the construction of grid-connected plants up to roughly 1 MW, but could also include the development of smaller projects (up to 100 kW) to serve isolated communities and small rural enterprises. The machinery required for this scale of development could go up to units of about 500 kW. Larger plants would be arranged in multiple-unit configurations of two or more turbo-generators. The turbines, their housing chambers and base plates, gate valves, penstocks, trashracks, and some of the electrical and control equipment would be fabricated in-country. Generators and other precision components such as bearings and governors (as needed), would continue to be imported, at least in the short-run.

Projects would be implemented on a decentralized basis, possibly by rural electric cooperatives and other small utility systems, or private developers, if market conditions could be created for this type of development. Alternatively, ICE could contract with private companies to construct and manage systems on a site-by-site basis or in groups of several projects.

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[4]China is a case in point. During the past 20 years, China has launched a major small hydro program. There are currently 80,000 sites with an average capacity of 100 kW. Small hydro plants are said by the Chinese to serve one-third of the total rural electricity needs of China. The program, based on decentralized development and management (with financial and technical assistance from the central government) is expanding. The Chinese claim that small hydro currently contributes as much capacity to the total capacity growth of the country as large hydro.

RECOMMENDATIONS

It is proposed that a private sector-based approach to small hydro development be considered for Costa Rica. The key element of such a program would consist of a commercially-operated small hydro enterprise to manufacture and assemble small hydro turbines and machinery in standard designs for medium and high-head hydro installations in the capacity range of 10-500 kW. The firm would provide engineering services, as needed, to survey sites, draw up civil designs for sites, install equipment, provide training for operators, and service machinery.

Small hydro enterprise

Technology transfer is the underlying objective of many energy development assistance programs currently pursued by AID and other international donor organizations. This has proven to be a problematic process as undertaken in the classic arrangement: institutional and technical consulting is provided to national entities in the form of planning, technical, and training assistance, sometimes accompanied by limited capital assistance to support the development of one or more demonstration projects. In theory--and sometimes in practice--large in-flows of capital from multilateral funding institutions or donor countries follow these initial institution-building efforts to carry out extensive energy development programs.

Frequently, however, these assistance programs become bogged down in bureaucratic delays, misallocation of funds, and persisting technical problems. For example, individuals who are successfully trained may transfer to other positions before any meaningful progress is made. Or, sudden budget or political crises mid-way through projects may cause disruptions or total shelving of projects. NRECA has witnessed a number of cases where small hydro technology transfer programs of the government-to-government variety have run into difficulties such as these. Often, where government agencies have been given the task of developing technical designs, years have been wasted in painstaking experimentation and testing of turbines, literally, "reinventing the (turbine) wheel." In short, when technical and funding assistance is placed solely in the hands of government agencies to carry out new energy programs, many things can go wrong which limit the effectiveness of these programs.

The creation of a private entity, as suggested here, offers a very efficient, rapid means of contributing to the technology transfer objective of an AID-supported energy development program. Based on PRE's current interest in supporting small hydro ventures in appropriate AID countries, it is suggested that a joint-venture between one or more U.S. small hydro firms and a Costa Rican partner be established for this purpose. The new enterprise would, in effect, purchase U.S. technology, modified to meet the specific design parameters which are indicated by prevailing physical and technological conditions in Costa Rica. The U.S. partner would take an interest of possibly 49% in the new enterprise, which would have the option of buying out the U.S. share after a certain period. Several small U.S. firms have expressed their strong interest to NRECA in such a venture. The enterprise would not only serve as a supplier of equipment, but would offer a package of engineering and training services to prospective purchasers of its products. This could include "packaging" small hydro equipment (of generally lower capacity) with specific end-use equipment such as agricultural and timber processing machinery, home-use machinery for cottage industries, etc. The firm could also serve as a general contractor to "turn-key" projects if desired by certain customers.

Institutional considerations

Notwithstanding any economic arguments which might be made in support of the decentralization of Costa Rica's power supply development program from the national welfare standpoint, there remain a number of potential obstacles to the implementation of a national small hydro program. From the viewpoint of the proposed small hydro enterprise, the issue boils down to whether a market exists in Costa Rica for small hydro units; that is, whether the project is commerically viable.

It was noted that ICE does not indicate any particular interest in developing small hydro sites, for reasons given at the beginning of this report. A recent study done for ICE on the feasibility of two representative small hydro sites concludes that extension of the grid would be more cost-effective than the small hydro option (although it appears to ignore the fact that extending the grid does not eliminate the need--nor the cost--of providing new capacity to serve new loads). To be sure, the administrative cost of implementing and managing many scattered projects by the central authority fundamentally limits the attractiveness of such an approach anyway. An alternative would rest with smaller, local utility systems, such as cooperatives and municipalities, as has been done in the Philippines, where some 250 sites (average 1 MW) are being implemented primarily by rural electric cooperatives under the overall direction of the National Electrification Administration. The problem with this approach is that Costa Rican cooperatives are, at present, too few to make much of an impact. A third alternative would be with private producers (most likely small and medium rural enterprises). Again, the expected response from this sector would also likely be insignificant, in the absence of incentives to encourage private investment in small hydropower.

However, the overriding constraint, looking to the cooperatives or private producers to carry the ball, is that they currently enjoy generally reliable electrical service at very low, subsidized rates. For example, the cooperatives currently purchase electricity from ICE at an average rate slightly over 1 Colone/kWh. It would be very unlikely that small hydropower could compete with these rates, meaning that at present, the market for small hydro units would be rather weak, and generally limited to potential buyers in regions which are not presently served by the grid nor likely to receive grid service in the near future.

The general conclusions from this discussion are that:

- o decentralized implementation and management of small hydropower projects is the most desirable, if not essential, approach; and

- o the institutional and financial environment in Costa Rica—in view of ICE's apparent reluctance to pursue small hydropower and the tariff subsidies it offers to other potential developers—presently renders small hydro impractical as a national energy development policy.

It therefore appears necessary that certain preconditions will be required before a meaningful national small hydro development effort is possible. First, the GOCR must establish a national policy committing itself to the development of small hydro resources. This will depend, in part, on the results of additional studies, proposed in the following section, to determine the full economic consequences of such a program. Second, subsidies built into the Costa Rican tariff system must be reduced, and ideally, eliminated, in order to permit rational decisions on the part of energy policy-makers,

producers, and consumers alike to be possible. There appears to be some movement in this direction, undoubtedly due in part to terms imposed by the IMF on the GOCR to "increase rates charged to citizens for utility services." Third, a system of incentives may be needed to stimulate small hydro development by independent producers, which would probably be the most cost-effective approach. These incentives, in view of the potential economic value of small hydro plants to the country, could be worthwhile and needed whether or not the foregoing two conditions are met.

Several incentive options exist, which can be considered individually or as a package, based on the legislative framework created under the Public Utilities Regulatory Policies Act of 1978 (PURPA) in the U.S.[5] Perhaps the strongest of these incentive mechanisms would be to guarantee a market for the sale of electricity to utility systems by independent producers. Typical examples of this in the Costa Rican context could include power purchase agreements between rural electric cooperatives and ICE, or even purchase agreements between private entrepreneurs and cooperatives or municipal utility systems (e.g. Matamoros -- Coopelesca). Ideally, purchasing utilities would be required to enter into such agreements on the basis of their "avoided costs" (by not having to generate the electricity themselves or purchase it from another source). Licensing procedures would be established within a national authority (possibly SNE) to authorize site developments, and regulations would be published giving guidelines for design and operating standards (including reliability), and the terms governing power purchase contracts. These terms would necessarily be based on economic criteria to ensure that tariff subsidies and other economic considerations (such as the foreign exchange cost of large hydro plants) are correctly reflected in the avoided cost formula. Purchase contracts would be based on prescribed kWh rates, with credits allowed for reliable or peaking capacity that can be made available by the seller.

Other institutional measures which would improve the effectiveness of this approach would include favorable credit programs and other financial incentives to promote the development of small hydro plants. These could include tax incentives to private developers, and possibly import duty concessions for small generators and accessory equipment used in small hydro plants.

It is recognized that the institutional apsects of this proposal pose a considerable political challenge. However, if it can be established that Costa Rica stands to gain substantial economic benefits--including the foreign exchange savings disucssed in this report—political obstacles could be overcome, should such a persuasive economic argument be possible. It is left to verify whether this argument in fact exists.

Follow-up

The recommended general steps for developing a national small hydro program in Costa Rica are:

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[5] A paper produced by NRECA entitled, "The Contributions of Legislative Initiative such as PURPA Towards Involving the Private Sector in the Development of Small Hydroelectric Power Plants in Developing Countries" is appended to this trip report. It discusses in some detail the regulatory framework of PURPA and some of the salient issues regarding its application to developing countries.

- o A programmatic study of main issues to determine if the basic ingredients are in place to support a national program, and to obtain the necessary institutional support to carry it out;

- o A technical study to gather a representative inventory of sites, prepare standard design parameters, conduct cost estimates, identify institutional and financial requirements, etc.;

- o Technology transfer through the creation of local manufacturing and engineering capability, plus supportive technical assistance and training, as needed;

- o Institutional reform to establish policies and laws conducive to small hydro development as determined by foregoing studies;

- o Financial intervention to create credit facilities to support project development; and

- o Implementation.

The issues requiring analysis in the studies described above include the following:

- o Are there, in fact, a sufficient number of potential small hydro sites upon which to base a national program?

- o To what degree could such sites contribute economically to national energy needs in view of hydrologic conditions, their proximity to load centers or transmission facilities, and alternative generating sources (including large hydro stations, geothermal and biomass energy resources)?

- o What rates of growth in electrical energy demand and generating capacity requirements are likely in Costa Rica during the next 25-50 years?

- o What are the true economic advantages of local-design hydropower plants based on the savings of foreign exchange and other economic considerations?

- o Would an institutional framework for the decentralization of power generation along private-sector lines be politically practical, and what steps are needed to institute such a system?

- o Are local partners, having the basic technical and physical resources (e.g. workshop) and access to capital present who are interested in a joint-venture to manufacture and engineer small hydro systems?

- o What are the standard design parameters for equipment and civil works for constructing numerous small hydro installations at competitive costs?

It is proposed that a team of specialists be provided to assess these issues. NRECA is currently preparing to conduct a general assessment of rural electric cooperatives in Costa Rica, including a management audit of Guanacaste electric cooperative, at the request of AID/San Jose. The proposed small hydro team, to include an institutional/economic advisor and a small hydro engineer, could be included as part of the presently planned effort to assess the relative merits of expanding the

decentralization of Costa Rica's rural electric system. This effort should take from four to seven weeks in Costa Rica, depending on the access to and quality of available data. This assistance could be funded as follows:

ITEM	SPONSOR
Institutional/Economic Advisor	AID/ S&T/EY (SDH Program)
Small Hydro Engineer	AID/ S&T/EY (SDH Program)
International travel	AID/ S&T/EY (SDH Program)
Local per diem cost	AID/San Jose
Local transport	AID/San Jose

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THE CONTRIBUTION OF LEGISLATIVE INITIATIVES SUCH AS PURPA TOWARDS INVOLVING THE PRIVATE SECTOR IN THE DEVELOPMENT OF SMALL HYDROELECTRIC POWER PLANTS IN DEVELOPING COUNTRIES

FINAL REPORT

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1.0 INTRODUCTION

The involvement of the private sector in managing small hydroelectric power projects in developing countries brings with it the possibility of a quick and efficacious development of a nation's hydroelectric resources. By their nature, small hydro projects are attractive propositions for the entrepreneur:

- Geographical dispersion of sites minimizes the stress on a nation's infrastructure.
- Project scale permits its development by a small group of professionals in a relatively short space of time.

The development of small hydropower power plants (SHPP) by the private sector is helped when a market is guaranteed for the plant generated energy at an attractive price. The developer can then negotiate a capital loan from a bank to finance the SHPP construction and operation. In this context, the promulgation by the U.S. Congress in 1978 of the Public Utilities Regulatory Policies Act (PURPA) is a very promising development. Of particlar relevance are Sections 201 and 210 of the act. These sections mandate electricity utilities to purchase electricity from any small producer (of capacity of up to 80 MW and which uses renewable resources as its primary energy source) at the price that reflects the incremental cost to the electric utility of alternative electrical energy. On the other hand, PURPA mandates that sales of supplementary and backup power by the utility to the small producer shall not be discriminatory and that they reflect the utility's average cost of electricity generation.

This paper then considers the contribution of legislative initiatives such as PURPA towards fomenting the involvement of the private sector in the development of small hydro electric power plants in developing countries. Elements of the U.S. approach that are appropriate for developing country application are emphasized. Other in-country factors that would be indispensable for transferring the PURPA model are explored. The paper is divided in the following sections:

- A major U.S. Initiative: The Promulgation of PURPA
- Applicability of PURPA to Developing Countries.
- Draft Policy.
- Example of a PURPA Situation.

2.0 A MAJOR U.S. INITIATIVE: THE PROMULGATION OF THE PUBLIC UTILITIES REGULATORY POLICIES ACT (PURPA)

The promulgation in 1978 of the Public Utilities Regulatory Policies Act (PURPA) has played a major role in renewing interest in the development of Small Hydroelectric Power Plants (SHPP) in the U.S. Extracts from Section 2 of the Conference Report point to the interest of the U.S. Congress in this issue:

"The Congress finds that the protection of the public health, safety and welfare, (and) the preservation of national security ... require

(1) A program providing for increased efficiency in the use of facilities and resources by electrical facilities (and)

(2) A program to provide the expeditious development of hydroelectric potential at existing small scale dams to provide electric power.

Title II of PURPA contains provisions that are without precedent world-wide (Taubman and Weingart, 1981), namely the use of legislative fiat to govern the purchase of power from two types of electric power generators-small power producers (including SHPPs) and cogenerators. Specifically, Section 210 of PURPA was designed to circumvent three obstacles faced by small power producers that desired to interconnect with an electric utility (Silverstone, November 1980):

- First, heretofore, electricity utilities were not required to purchase electricity generated either on an "as available" or firm contract basis even if the electricity were offered at a favorable rate.

- Second, backup power sales to small power producers, who usually met all or most of their own needs was often priced at a discriminatory high rate.

- Third, even if a small power producer were permitted to supply energy to a utility, it ran the risk of being deemed a utility and thereby being subject to a plethora of federal and state regulations. Compliance with such regulations could often be much more costly than any economic benefits that could accrue from the sale of electricity.

Section 201 in conjunction with Section 210, addresses each one of these impediments and to varying degrees eliminates or substantially reduces them.

2.1 Discussion of Relevant Parts of Sections of 201 and 210 of PURPA

Important provisions of Title II of the Public Utilities Regulatory Policies Act (PURPA) are listed in Appendix I. In essence, they provide the framework that determines the purchase of electricity by electric utilities from qualifying small power production facilities (QF) at a rate consonant with the incremental cost to the utility of alternative electrical energy. A QF is defined to include facilities of capacity no greater than 80 megawatts that produce electric energy primarily by the use of a renewable resource (including hydroelectric) and of which no more than fifty percent of the equity interests is owned by an electric utility.

PURPA also requires that the rates for the sale of electricity by an utility to a QF shall not be discriminatory and that QFs be exempted from federal and state laws and regulations that pertain to electrical utilities. A further mandate of PURPA calls for "rulemaking provisions respecting (a) minimum reliability of qualifying ... facilities (including reliability of such facilities during emergencies)" and (b) "reliability of electric service to be available to such facilities from electric utiities during emergencies."

Additionally, Congress had directed the Federal Energy Regulatory Commission to promulgate rules to guide the implementation of Sections 201 and 210 of PURPA after "appropriate consultation with representatives of Federal and State regulatory authorities having ratemaking authority for electric utilities" and the general public. Finally, Section 210(f) defines the role which states are required to perform in the PURPA regulatory structure by requiring that each state regulatory authority shall after appropriate consultation with the general public," implement such [FERC] rule (or revised rule) for each electric utility for which it has ratemaking authority".

2.2 Federal and State Implementation of Selected Provisions of TIRE II of PURPA

2.2.1 FERC Promulgation of Rules

On February 25, 1980, FERC issued its final set of rules under Section 201 and 210 of PURPA (to be codified as 18 CFR §292). Broadly, the regulations cover the following issues: (1) electric utility reporting requirements; (2) purchase rates; (3) sales rates; (4) interconnection costs; (5) required characteristics of qualifying facilities such as a) ownership; b) operating and efficiency standards; and c) certification and d) exemptions from federal and state law. In general, the rules are designed to make it exceedingly worthwhile for QF's to sell electricity to any (inter)connected utility at an agreed purchase rate.

The purchase rate of electricity from a new QF (i.e., built after 11/9/78) by an electric utility will depend upon the avoided costs (which are the FERC defined proxies for incremental costs as mentioned in PURPA) plus the characteristics of the QF system itself. Avoided costs are "... the incremental costs to an electric utility of electric energy or capacity or both which, but for the purchase, from the qualifying facility or qualifying facilities, such utility would generate itself or purchase from another source" (Section 292.101 (b)(6))[45 FR 12214 (2/25/80)]. The data reporting requirements of the utilities have been designed to assist the competent state regulatory agencies in determining the avoided costs. These include: 1) the estimated avoided energy costs (¢/kWh) for various levels of purchases from QFs. Data must include costs of daily and seasonal peak and off-peak periods for the current year and each of the next five years; (2) the utility's plan for additions to or retirements from capacity (by type and amount) and any purchases of firm energy and capacity for the next ten years; and (3) estimated capacity costs in dollars per kilowatt and associated energy costs per kilowatt for each planned capacity addition or planned firm purchases [Section 45 FR 12214 (2/25/80)].

Data provided by the QFs which may also be considered in calculating the avoided costs include (1) availability of capacity or energy during

daily and seasonal peak periods (including dispatchability, expected or demonstrated reliability); (2) contract terms with the utility (including duration of purchase obligations; termination notice requirements and sanctions for non compliance); (3) coordination of scheduled outages; (4) usefulness of QF capacity and energy during emergencies, including ability to separate its load from its generation; (5) the individual and aggregate value of energy and capacity to the electric system. Also, the relationship of the availability of energy or capacity and the ability of the utility to avoid costs (including the deferral of capacity additions and the reduction of fossil fuel use plus the costs or savings resulting from line losses) may be taken into account (Section §292.304(E)]

Each state regulatory authority has the option of weighing the above mentioned factors as it sees fit, of utilizing and promulgating standard purchase rates throughout its service area for each type of QF (such as wind energy conversion systems (WECS) or SHPPs) or of examining the factors on a case by case basis (for facilities of capacity greater than 100 KW only).

FERC rules for sales rates by utilities to QFs are couched in terms of average costs of electric energy generation and provisions of generating capacity. Rates shall not discriminate against any QF in comparison to other customers of the same class who do not generate electricity for supplementary, backup, maintenance, and interruptible power. Also rates for backup and maintenance power must reflect the extent of coordination between scheduled outages of the QFs and the utility's facilities.

The above discussion has touched lightly on the rules that have been issued by the FERC to facilitate implementation of Section 201 and 210 of PURPA. More detailed analyses of the rules have been made by Silverstone (1980, 1981), Golden (1981), and the Energy Law Institute (1980). The work of Fox (1981) is particularly useful in developing a methodology for calculating avoided cost. Finally, it bears noting that small projects, such as SHPPs will only gain substantial allowances for avoided capacity costs if considered in the aggregate for both size and reliability criteria.

2.2.2 Implementation of FERC Rules by State Regulatory Authorities

PURPA and the FERC regulations promulgated thereto do not specify a specific implementation plan for the states. Each state is given broad

procedural and substantive latitude in formulating its response to federal directives which thereby permits it to implement PURPA with greater sensitivity to local conditions and with innovative methodologies. A well conceived state implementation plan will reflect state policy objectives and regulatory principles and have a rulemaking procedure that minimizes demands on state fiscal and administrative resources and that addresses directly the issues and concepts relating to rate structure and design on a technology option basis. Then, regulations would be established that would be applicable statewide to all utilities and QFs.

The state utility commissions were required to promulgate implementation plans for carrying out the mandate of Sections 201 and 210 of PURPA by March 20, 1981. As of early June 1981, only 15 states had implemented FERC rules regarding PURPA small producer rules (Hydrowire, July 1981). As expected, the standard purchase rates are heavily influenced by the fuel (such as nuclear, coal, or fuel oil) that the purchased power would replace. Sample purchase rates are shown below (Pope, 1981).

State	Intermittent Power (¢/kWh)	Constant Power (¢/kWh)	Displaced Fuel
New Hampshire	7.7	8.2	Fuel oil
North Carolina	3.0	5.0	Nuclear
Vermont	6.6	9.0	Fuel oil

2.3 Impact of Private Sector Involvement on Small Hydro Development

In April, 1980, the Federal Energy Regulatory Commission (FERC) in an Environmental Impact Assessment estimated that PURPA would stimulate the building by non-utility controlled entities of 12,000 MW of capacity by 1995 (for all renewable resource technologies plus cogeneration).

However, already it seems that the FERC's estimate is unduly conservative. In 1981, the FERC expects to receive 1,800 applications to study hydro- generation at existing dams and in developement sites - a hundred fold increase from just 18 in 1977 (Norman 1981). Most of the applications deal with sites that meet PURPA requirements, albeit approximately half of them compete for the chance to develop existing dams. As of April 1, 1981, private entreprenueurs had filed applications representing 5,674 MW with the FERC (Gallant, 1981).

The proposed projects are scattered throughout the country and involve installing SHPPs in places such as impoundments of abandoned textile mills (in New England and the Southeast), irrigation dams (in the Northwest) and at locks in major rivers such as the Mississippi, the Missouri, the Arkansas, and the Alabama.

A noticeable feature of private sector involvement in small hydro development is that a new kind of company is entering the field. Typically, this kind of company aims to develop small hydro on a large scale and specializes in putting together "package deals" that include (1) the management of a project through all its regulatory, technical, and financial aspects, (2) developing a contract to sell the SHPP output, and (3) formulating a scheme to attract investors.

A typical contract between a QF and a facility would require that:

- The QF be responsible for constructing, owning and maintaining the hydroelectric plant;
- The utility would be responsible for constructing, owning, operating and maintaining all the distribution and substation connection facilities required to connect the QF and the utility,
- The QF would reimburse the utility for all the initial distribution and substation facility connection costs and pay an annual fee to the utility for O&M of the facilities (Barkovich, 1981).

2.4 Technical Issues

The incorporation of qualified facilities in the generator/load mix of a given utility will occasion a review of the utility planning and operating practices. As a minimum the following technical concerns will need to be addressed:

- safety to personnel and equipment
- quality of service
- operational accommodations
- metering
- sizing procedures and interconnection limits
- installation data needs.

None of these concerns are insurmountable. Prichett (1981) has delineated possible procedures for dealing with them. However, clear guidelines need to be established on who is going to pay for any special equipment and/or labor consuming procedures that will be involved.

3.0 APPLICABILITY OF PURPA TO DEVELOPING COUNTRIES

The circumstances that induced the U.S. Congress to promulgate the Public Utilities Regulatory Policies Act (PURPA) in 1978 apply even more in developing countries whose economics have been devastated by the oil price increase since 1973. The massive payments for oil imports have soaked up a growing share of the export earnings of these countries, strained their ability to pay for essential imports and slowed down their economic development. Thus the development of all viable renewable sources of energy (including small hydro) is imperative (from both national security and economic well being viewpoints) for developing countries.

For many countries, the optimal development of its indigenous hydroelectric resources will need a partnership arrangement between the public and private sectors. The existence of legislation, such as PURPA, that guarantees an attractive market price for electricity generated by qualified facilities is a necessary but not sufficient step for involving the private sector in the development of Small Hydroelectric Power Plants (SHPP's) in developing countries. This section first delineates other factors that influence SHPP development by the private sector and then reviews those elements of the U.S. PURPA that may be applied in developing countries.

3.1 Factors that Influence SHPP Development in Developing Countries

Some factors that need to be considered in judging whether SHPP development by the private sector is viable are:

- *A national awareness of the importance of fomenting small-scale energy projects* by the public and private economic sectors and the general public is vitally necessary to get rapid action. This is especially important in countries where the production potential of small energy resources is so large that it may make a significant contribution to the energy supplies country-wide.

  In practise, this awareness translates into a positive attitude on the part of all public and private entities that may influence the success of small hydroelectric projects.

- *Sensitivity to overcoming institutional problems.* For example legally in India, SHPP projects cannot be developed by the private sector (Barnea 1981). In most countries in Latin America, water use for food production has the first priority such that hydroelectric projects are always subordinated to the use of water for irrigation. Thus it is important that clear rules define the involvement of the different entities interested in water resources development (Indacochea 1980).

- *Eenergy organizations charged with planning the development of the nations energy resources* can highlight the importance of developing hydroelectric and other renewable resources. Such organizations can also influence electric utilties in developing tariff structures that reflect the true cost of fossil fuels and encourage the incorporation of hydroelectric and other renewables into their energy supply mix.

  Since many SHPP service areas will be in rural areas, such an energy planning organization could also be used in catalyzing the coordination of the activities of energy development entities with those of agriculture and rural development agencies.

- *Existence of a public utility commission*, with the responsibility to regulate the orderly development of the electricity sector and especially to regulate electricity tariffs.

- *Availability of capital for construction* is a major concern to private developers. Clasgens and Rothchild (1981) have listed many mechanisms for financing SHPP projects including tax-exempt bonds and debt-services guarantees. The State of California for example has created the California Alternative Energy Source Financing authority to issue tax-exempt bonds to make low-cost funds available for solar, wind, biomass, geothermal and SHPP projects.

- *Government debt service guarantees* reduce project risk and thereby stimulate private sector interest in SHPP development, at little or no cost in tax revenues. If rigorous screening of projects takes place to minimize the possibilities of default, the program can operate at virtually no cost. A standardized technical and financial project appraisal procedure is also necessary in minimizing program costs (Marsden, 1981).

- *The availability of drought insurance* especially for the early SHPP operating years is also important.

- *Flexibility in the possible contracting arrangements between* the utility and the SHPP developer is another important issue. The possibility of the utility giving a contract that would allow the SHPP to pay back all loans in the first 5 years after the plant is operating would make many projects very attractive. (Merrill 1981).

- *Availability of programs for training possible project managers technologists and technicians* for planning, design, construction and operation of the SHPP's is vitally important. Wherever the prospects for obtaining trained personnel are poor, investments become risky, and credit will not be available.

- *A high level of local community interest and participation in small energy projects and similar (water sanitation projects)* is an important factor. The involvement of the local community helps SHPP projects in lowering project costs (especially civil engineering costs) and improving reliability of operation through maintenance of the watershed upstream from the headrace entry point and concern for proper plant operation.

3.2 Elements of the U.S. PURPA That May be Applied to Developing Countries

In the context of this paper, the most important objective of PURPA is to incentivate the rapid development of a nation's renewable (including hydroelectric) resources through a partnership of the public and private sectors. A measure of the efficacy of PURPA will be the rate that new renewable systems (including SHPP's) are integrated into the national grid and the subsequent reliability of the new systems.

For developing countries, any PURPA style initiative will have to be promoted within the context of each nations legal/socio-economic milieu. What is important is to bear in mind the five principal assumptions of sections 201 and 210 of PURPA:

- Only qualifying facilities can sell electricity to the utility. The QF will be defined in terms of its ownership structure, its size and the resources it uses for generating electricity.
- The utility will purchase electricity at a rate consonant with the incremental cost to the utility of generating electricity.
- The utility will not discrimate in its sale tariffs against QF's.
- The QF's will be exempt from the legal and regulatory requirements governing the organization and financial reporting of electrical utilities.
- The QF's and the utilities will be expected to meet minimum specified reliability requirements in furtherance of the objective of PURPA.

The actions taken by the Federal Energy Regulatory Commission (FERC) and the Public Utility Commission (PUC's) shoudl be judged strictly on their applicability to the reality that exist in each country. The concept of "avoided cost"that takes into account both the capacity and the amount of electricity provided by the QF to the electric utility seems a useful one. Likewise the criteria that may be used in determining the reliability of service provided by the QF to the utility are helpful.

As time progresses, a rich lode of experience is being generated on the efficacy of PURPA in the U.S. It may be interesting monitor the situation in a state such as California, where already a number of utility-private sector SHPP contracts have been signed (Barkovich 1981) with the objective to finding out what kinds of arrangements are proving to be the most satisfactory.

There is one element that must be accounted for in many developing countries in a PURPA type initiative that is not contemplated in the U.S. law. This is the active participation of the local community in the construction and operation of the SHPP to help ensure its reliability of peformance. Experience in many countries has shown that SHPP's are often out of service because of poor maintenance of the watershed upstream of the diversion dam. This adverse situation can be avoided when the local community knows that the continuation of their electricity service depends uniquely on how well they conserve "their" watershed.

4.0 DRAFT POLICY

For many countries, the optimal development of its indigenous resources will need a partnership arrangement between the public and private sectors. Clearly, a PURPA type initiative is a necessary step for stimulating the involvement of the private section in mid or higher level developing countries. In such cases, the vitality of the private sector's contribution to small hydro development would be enhanced if public policy followed the lines mentioned below.

- The national legal infrastructure (including the pertinent electricity sector and water resources law) would permit participation of the private sector in the development of small hydro sites and guarantee the subsequenct sale of electricity to the electrical utilities (using a wide range of possible contract mechanisms).

- An energy planning organization be put in place with the mandate to plan for the rational development of the nation's energy resources and to coordinate all energy development activities.

- Availability of capital for SHPP construction (using mechanisms such as tax-exempt bonds and debt service guarantees) would be assured.

- Clear rules delineating the role and responsibilities of foreign resources (capital, technical) would be promulgated including guidelines for the establishment of joint ventures with host country firms.

- Drought insurance would be made available where appropriate.

- Training programs for SHPP project managers, technologists and technicians would be put in place.

- The role of local communities in the development and operation of SHPP's would be highlighted through the provision of educational outreach programs in rural communities on the benefits of electricity and on the important role these same communities will play in guaranteeing reliability of its supply. The local communities will benefit from their involvements in the development of small hdyro systems through electrification on favorable terms.

Figure 1 shows the interrelationship of the public and private sectors in the development of SHPP's when a PURPA style initiative is used.

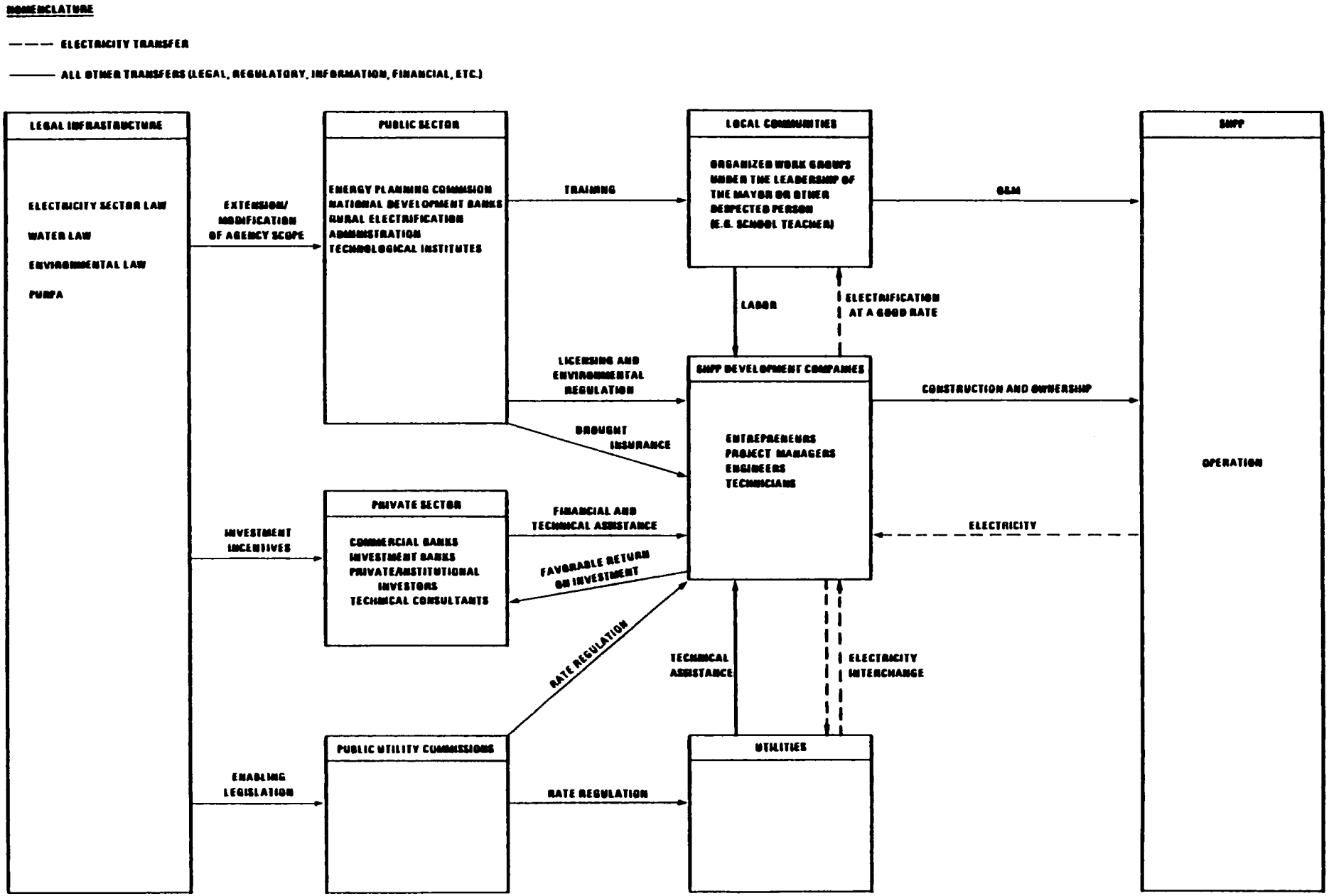

FIGURE 1 INTERRELATIONSHIP OF THE PUBLIC AND PRIVATE SECTORS IN THE DEVELOPMENT OF SHPPs

5.0 EXAMPLE OF A PURPA SITUATION

In this section, a real example from the Dominican Republic has been chosen to demonstrate how the application of a key provision of Section 210 of PURPA (i.e., the purchase price of electricity by a utility from a small producer should reflect the utility's avoided cost) could make the development of a SHPP very attractive for the private sector. The situation as described below is a summary of a detailed study (NRECA, July 1981) that was conducted using a customized site selection methodology (NRECA, June 1981). This methodology reflected current standard engineering practice in the United States and the Dominican Republic. The discussion is divided into 2 parts: (1) engineering review of the project; and (2) financial review of the project.

5.1 Engineering Project Review

The engineering review of the project begins by looking at the site characteristics in terms of location, hydrology, and topography and then develops a design that optimizes the site electricity generation capabilities.

Site Characteristics: The site is located in Azua Province with the proposed location of the powerhouse about 1 km distance from a 12.5 KW distribution line. The drainage area of the watershed associated with the intake to the power canal was 200 km^2 in surface area. Five years of pertinent stream flow data were available.

Design Considerations: Using information provided by a flow duration curve and following the procedures laid down in the site selection methodology, a design flow (Q_d) of 1.5 m^3/sec was determined. A number of project configurations were considered that depended upon project layout and single vs. multiple turbine arrangements. The optimal configuration chosen was a cross-flow turbine of 726 kW capacity based on a design head of 61.75 meters and potential annual generation of 2.41 GWh. Further engineering details of the project are shown in Table 3.

The project also included the following features:

- A diversion rock and concrete dam 36 meters long and 3 meters high;
- A 2.3 KM trapezontal rock and mortar tailrace with a gradient of 0.01 and a flow capacity of 1.7 m^3/sec;
- A 36" diameter steel penstock of 8mm thickness, 100 meters length and 1.5 m^3/sec capacity;
- A synchronous 726 KW generator with a voltage rating of 4160 volts at 60 Hz and a speed of 1200 rpm (through a stepped speed increaser);
- 7 km of 12.5 kV transmission line.

5.2 Financial Project Review

The financial review of the project first estimates the project costs, then estimates the project benefits and finally evaluates the project in terms of internal rate of return, benefit-cost ratio, and net benefits.

Project Costs

The following assumptions prevailed in determining the costs:

1. The equipment and material costs reflect the price as delivered to the site.
2. All costs are expressed in terms of 1981 RD$. All equipment that would be procured abroad was costed at the official exchange rate of 1 RD$ = 1 U.S. $.
3. The cost of labor in construction and installation is assigned a value that is a weighted average of local labor costs and semi-skilled labor cost.

Table 1 presents a summary of the project costs as prepared by a team of professionals from the Dominican Republic while following the above-mentioned site selection methodology.

Project Benefits

The project's benefits are calculated as the revenues from the sale of the annual report of electricity generated at the assumed grid purchase rate of 11¢/kWh. This is the average cost of generation of electricity

TABLE 1
ESTIMATED PROJECT COSTS

		RD$
1.	New Dam and Spillway	105,000
2.	Power Canal	198,700
3.	Power Intake	24,000
4.	Penstock	56,000
5.	Power Plant and Electrical Equipment	405,800
6.	Transmission Line, Transformer and Protection Equipment	102,000
7.	Land Clearing and Access	14,000
		950,000
Admin. and General Expenses (10%)		95,100
Contingencies (15%)		142,600
		1,188,200

for the National Electrical Utility (CDE, 1980). It is calculated as follows:

	Cost per kWh
Operation	9.15
Maintenance	0.42
	9.67

At an annual inflation rate of 15% for 1981, this comes to 11.12 ¢/kWh. The following additional assumptions are made:

1. All capital costs will be incurred prior to the first year of operation (C_o).

2. Recurring costs for year i (R_i) include 1.28% for operation and maintenance (O&M) and 0.01% for administration and general expenses (A&G), as percentages of capital cost.

3. The discount factor represents the opportunity cost of capital, officially set at 12%.

The procedure for calculating the present value of the project benefits, costs and net benefits is shown in Table 2 plus the pertinent calculations for this example. The results may be summarized as follows (1981 dollars):

The total present value of the project benefits (PVB_{30}) = RD $3,415,720
The total present value of the project costs (PVC_{30}) = RD $1,311,665
The total present value of the net project benefits ($NPVB_{30}$)= $2,104,055

The benefit cost ratio = 2.60

The project internal rate of return is 34%.

5.3 Institutional Considerations

The previous two subsections have shown the feasibility (both financially and technically) of developing a real site in the Dominican Republic. Financially the project is very attractive. In fact the project benefits have been underestimated because the analysis assumed:

Table 2

CALCULATION OF THE PRESENT VALUE OF THE PROJECT BENEFITS AND COSTS

For a planning horizon of 30 years the total present value of the benefits (PVB_{30}) is:

$$PVB_{30} = \sum_{i=1}^{30} B_i \frac{1}{(1+r)^i} \quad ....(1)$$

In this case B_i is constant (B) for each year of the planning horizon and

$$B = 0.11 \text{ \$/kWh} \times 3.855\times10^6 \text{ kWh} = \text{RD \$424,050}$$

and remembering that the present value factor PVF_T is defined as

$$PVF_T = \sum_{i=1}^{T} \frac{1}{(1+r)^i} = \frac{1-(1+r)^{-T}}{r} \quad \text{where,}$$

T is the length of the planning horizon (Maass, 1962).

In this case,

$$PVF_{30} = 8.055.$$

Thus equation (1) may be re-written

$$PVB_{30} = PVF_T . B$$

$$= 8.055 \times \text{RD \$424,050} = \text{RD \$3,415,720.}$$

The total present value of the project costs (PVC_{30}) is:

$$PVC_{30} = C_o + \sum_{i=1}^{30} C_i \frac{1}{(1+r)} = \quad ..... (3)$$

In this case,

$$C_i = (0.0129)C_o, \; i = 1, 2... 30$$

Thus equation 3 may be re-formulated as:

$$PVC_{30} = C_o + 0.0129 \; PVF_{30} \; C_o$$

$$= C_o \; (1 + 0.0129 \times 8.055) = \text{RD\$ } (1{,}188{,}200 \times 1.104)$$

$$= \text{RD\$ } 1{,}311{,}665$$

The net project benefits ($NPVB_{30}$) are calculated as follows:

$$NPVB_{30} = PVB_{30} - PVC_{30} = \text{RD\$2,104,055}$$

1. The utility's average rather than marginal cost of electricity generation;

2. No real increases in imported petroleum costs over the planning horizon;

The prima facie evidence shows that this project is extremely attractive for the private sector. An analysis was made of the factors listed in Section 3.1 that could affect the feasibility of this project being brought to fruition by the private sector. The results of the analysis are shown in Table 3. Essentially, the prognosis for private sector development of SHPP sites in the Dominican Republic is good, but not at this time.

The current impediments to SHPP development in the Dominican Republic by the private sector are primarily institutional. What is needed are the following:

1. The promulgation of a rational Electrical Sector Law (ESL) that clearly defines institutional responsibilities for the generation, transmission, distribution and sale of electricity. The law will carefully delineate institutional responsibilities for hydroelectric resources development;

2. The ESL will also mandate the establishment of a public utility commission (PUC) that will oversee the rational development of the electricity sector;

3. The promulgation of a PURPA style law to optimize the contribution of both the public and private sectors in SHPP (and other renewables) development. The general characteristics of the law are outlined in Section 3.2.

TABLE 3 ANALYSIS OF THE EXISTI JATION IN THE DOMINICAN REPUBLIC
CONCERNING SHPP DEVEOP .. BY THE PRIVATE SECTOR

FACTOR	SITUATION
A National Awareness of the Importance of Fomenting SHPP	Feasibility SHPP studies have been conducted under the aegis of many foreign governments and agencies (including USAID, KfW, Canada, France, Norway and Spain) in conjunction with Dominican Republic Government Agencies. Two SHPP's are in operation; 1 is under construction. Construction will begin on 3 more in the near future. USAID is contemplating financing at least 3 more SHPP projects.
Existence of an Energy Organization Charged with Planning the Development of National Resources.	A permanent National Energy Policy Commission (CNPE) was established in 1979 to help coordinate the energy-related activities of different agencies, analyze the national energy situation and identify and promote appropriate energy policies and programs. CNPE has established a hydroelectric unit that has the responsibility for the preparation of short, medium and long-term plans and policies for hydroelectric generation. The National Electrical Utility (CDE) tariff structure is designed to put the utility on a solid financial basis.
Sensitivity to Overcoming Institutional Problems	Currently, only CDE can sell electricity. CDE has a barter arrangement with some large autogenerators of electricity to transfer energy back and forth at appropriate times. Legal situation on the development of hydroelectric resources is very unclear and has lead to turf battles between CDE and INDRHI (National Hydraulics Development Institute). A comprehensive study of the legal structure of the electricity sector is planned to get under way shortly that will eventually lead to the drafting and promulgation of a modern and efficient electricity sector law. The law may mandate the operation of an electrical utility regulatory commission.
Availability of Capital for Construction by the Private Sector	At present this is a moot point, since only CDE may sell electricity. The country has an active commercial banking system and more than 15 development lending institutions with ties to the central bank. One development institution (FIDE) has a policy, of nearly two years standing, of special treatment of loans designed for energy conservation in industry or agriculture or production of alternative energy devices.
Availability of Drought Insurance	No
Flexibility in Contracting Arrangements Between the Utility and the SHPP Developer	N/A
Availability of Programs for Training Possible Project Managers, Technologists and Technicians	The Dominican Republic has a cadre of well-trained professionals who are familiar with all aspects of SHPP development. CDE has in place a training program in O&M for SHPP operators.
Community Interest and Participation in Small Energy and Similar (Water Supply) Projects	Field trips by NRECA personnel and discussions at all levels of society attest to a widespread community interest in small energy projects and an active record of participation in previous water supply projects.

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