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ECONOMIC ISSUES IN SMALL HYDROPOWER DEVELOPMENT

by

Paul J. Clark
Training and Information Specialist
Small Decentralized Hydropower Program
National Rural Electric Cooperative Association

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Biographical sketch

Paul J. Clark, Training and Information Specialist for NRECA's Small Decentralized Hydropower (SDH) Program, is currently developing a handbook for economic analysis and planning of small hydropower projects.

Prior to joining the SDH Program staff in February 1981, Mr. Clark served on the professional staff of the U.S. Senate Budget Committee from 1977-81, where he was responsible for developing policy positions on national fiscal and monetary affairs. Mr. Clark also served for two years as legislative assistant to Senator Gary Hart (D.-Colo) for economic, energy, and tax policy issues.

Mr. Clark received his B.A. in political science from the Colorado College in 1972 and his M.A. in international studies/economic development from the American University in 1978.

ECONOMIC ISSUES IN SMALL HYDROPOWER DEVELOPMENT

I. Introduction

Economic analysis of small hydropower projects is essentially a comparative analysis of the costs of supplying energy from alternative generating sources within the context of specific site conditions. The basis for comparison depends on alternative energy supply means which are available to the energy planner. Most often the choices are large thermal or hydro-electric generating stations linked to a national or regional transmission grid, or small diesel generators in the case of isolated areas. Other energy technologies may also be considered: biogas systems, solar thermal or photovoltaic systems, geothermal energy systems, or wind energy systems. The determining factors in assessing which energy option offers the most cost-effective investment option are derived from site studies aimed at answering questions such as:

- What are the costs of extending the grid to the site?
- What is the delivered cost of diesel fuel?
- What are the unit installed costs of alternative energy generation systems, and how often must plant be replaced?
- What constraints exist on the availability of fuel, wind, water, sunlight, and biomass feedstock for energy generation at the site?

In addition to these questions are energy demand considerations which may affect the energy supply choice:

- Will energy demand be sufficient to warrant a large capital investment, such as an extension of the grid or construction of a hydropower scheme?
- Do energy demand patterns correspond with energy supply patterns, in the case of renewable energy technologies, which may offer only part-year or part-day generation?

Finally, in the case of projects which supply energy to small, isolated communities, issues relating to the ease of operation and maintenance, and the social acceptability of the energy system must be taken into account. The ultimate objective of economic analysis is to determine the net consequences of investing in small hydropower projects: do net benefits justify the investment? The first step is to establish the most cost-effective means of providing energy. The second step, if the small hydro option is competitive, is to determine the net return on investment.

II. Cost considerations

General statements on comparative costs of energy generation are not possible, since costs will depend on a wide range of conditions which may vary from case to case, both between countries and between regions within the same country.

Capital costs for alternative generating options in the developing countries as estimated by the World Bank in 1980 are shown in Table 1.

Table 1. Comparative capital costs of different generation options in oil-importing developing countries (1)

Generator Type		Investment Cost 1980 US Dollars per kW Installed[a]
Hydropower	- Large, High Head	1100
	- Low Head, Mini-Hydro	3500
Diesel	- Large, Heavy Oil Fuel, Coastal Location	1000
	- Small, Light Oil Fuel, Inland Location	800
Steam	- Large, Gas-Fired	800
	- Large, Coal-Fired	1000
	- Large, Oil Fired (Imported)	800
	- Small, Heavy Oil-Fired, Inland Location	1400
	- Small, Wood-Fired	1500
Geothermal	- Dry Steam Field	1400
	- Wet Steam/Hot Water Field	2800
Nuclear	- Large Multiple Units	1600
	- Single Small Unit	2200
Solar Photovoltaic		20,000-30,000[b]
Wind Generator		5,000-15,000[b]

[a] Investment cost includes costs of transmission and distribution.

[b] Both solar energy and wind power are intermittent energy sources which require storage to make energy available on demand at all times. Investment costs given above are system costs with storage included.

The figure shown for low-head mini-hydropower is not unreasonable, but experience has shown that the cost/kW installed of small hydropower projects in the developing countries is widely variable, depending on factors specific to each site. Some of the principal factors which influence capital costs include:

- Head availability. Higher heads tend to reduce unit costs since energy can be generated with less water than low-head sites, meaning equipment can be smaller and generally less complex.
- Water supply. Under ideal conditions, water should be plentiful, clean, and in supply year-round. Intermittent flows, which are not uncommon on many small rivers and streams, means that impoundment dams may be needed to store water during low-flow periods, increasing civil costs. Water which carries large amounts of rock and sediment may increase maintenance and replacement costs and necessitate the addition of settlement structures to remove rocks and sediment from the water before entering the penstock.

- Access difficulty. Difficult terrain surrounding the site may require considerable expenditures for access roads.

Another factor often cited as a major determinant of unit cost is the size of the plant. There is considerable debate on this argument, which holds that unit costs increase as plant capacity declines. Some say that there are unavoidable "fixed" costs in small hydropower plants of any size, including site inspection, engineering, management, and maintenance costs. Civil structures, including dams, powerhouses, and penstocks, and the turbo-generating equipment may cost less in absolute terms for a very small plant, but these costs do not decrease proportionally with capacity. In general, it is this view that economies-of-scale tend to make smaller hydropower projects unattractive as investment options.

While the economies-of-scale argument is difficult to dispute, given the experience of hydropower development in the industrial nations, the experience to date in the developing countries suggests that economies-of-scale may operate in reverse to some degree. Table 2 gives capital cost data for eighteen small hydropower projects built in the developing countries since 1971. A quick glance at this data shows that the average unit cost installed for plants under 100 kW in this group is approximately half that of the plants above 100 kW. The explanation for this phenomenon rests in the fact that

TABLE 2. Capital Costs for Small Hydro Plants in Developing Countries (2)

Country	Capacity (kW)	Head (m)	Cost per kW[a]	Equipment as % of cost	Comments
Thailand	800	40	$2,[illegible]50	15%	Concrete construction for civil works
Ecuador	400	4[illegible]	2,[illegible]00	36%	Lined canal; imported equipment
Ecuador	400	19	2,[illegible]00	30%	Lined canal; direct intake; imported equipment
Nepal[b]	200	58	[illegible]00	36%	Partly lined canal; loose-packed rock dam
Nepal	120	14	[illegible]00	21%	Masonry-lined headrace
Indonesia	120	1[illegible]	1,[illegible]00	58%	No headrace; local turbine
Thailand	100	7[illegible]	[illegible]50	21%	Concrete construction for civil works
Philippines[b]	100	2[illegible]	[illegible]50	38%	Local construction materials and turbine
Indonesia	90	19	1,[illegible]50	54%	Concrete-lined headrace
Nepal	80	16	1,[illegible]50	23%	Local materials and turbines
Nepal	80	34	1,[illegible]50	31%	Local materials and turbines
Nepal	25	22	[illegible]50	28%	Existing irrigation works
Indonesia[b]	15	22	[illegible]00	30%	No headrace or governor, used alternator
Thailand	15	10	2,[illegible]50	41%	Earth dam and headrace
Thailand	10	c	1,[illegible]00	27%	Lined canal; local turbine
Pakistan[b]	10	c	[illegible]70	61%	Local materials and equipment
Nepal	9.5	c	[illegible]00	46%	Local materials and equipment, except penstock
Pakistan[b]	7.5		[illegible]20	50%	Local materials and equipment

[a] Not including transmission and distribution costs.
[b] Projects implemented and managed locally.
[c] Precise heads unknown, but generally between 5-10 m.

standard, conventional approaches to the design and construction of very small plants may not be necessary. Case studies have been made of small hydropower programs in several countries where micro-hydro plants have been built on the basis of local initiative at very low cost. The major attributes of this unconventional approach are:

- the avoidance of conventional engineering concepts which require scaling down standard civil and mechanical components used in large hydropower plants to smaller sizes;
- the adoption of site study approaches based on "minimum needs" rather than maximum potential, reducing the need for exacting hydrologic data;
- the recognition of opportunities to improvise civil components, taking full advantage of locally available construction materials and labor; and
- the use of locally-fabricated turbines and accessories based on uncomplicated designs and simple construction techniques which are adequate to serve modest energy requirements.

To be sure, the economies of scale rule holds true, given the approach to development. Fig. 1 compares the capital cost curve for conventionally engineered projects with two alternative approaches to small hydropower development which have been documented in the developing countries. Each approach, represented in three different curves ranging from the very simple (Pakistan) to the more complex (conventionally built small hydropower plants in the U.S.), has its own economies-of-scale character. But taken together, the data shows that costs tend to increase with plant size, as confirmed by Fig. 2. The underlying thesis is that with very small projects, innovations are possible that are not now possible with larger plants. An alternative approach which helps to bridge the cost gap between unconventional (smaller) and

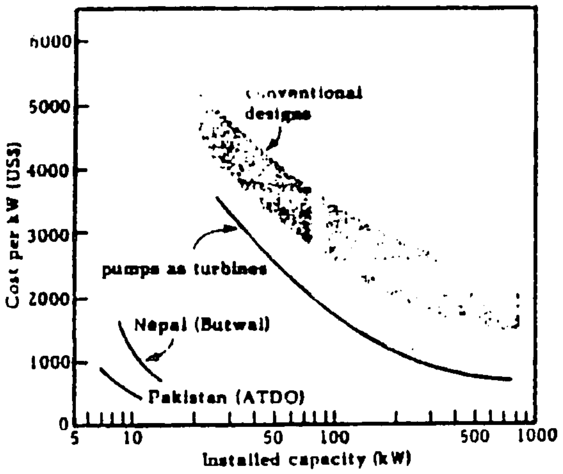

Fig. 1. Cost curves for different approaches to small hydro development.

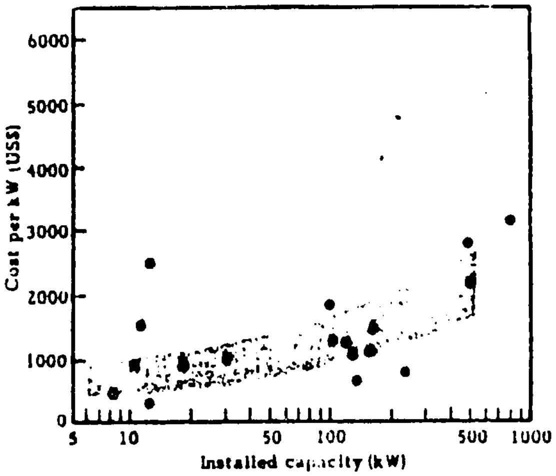

Fig. 2. Cost curve of small hydro plants listed in Table 2.

conventional (larger) plants would be to standardize certain components using off-the-shelf designs and equipment, as reflected in the pump-turbine curve shown in Fig. 1 (3).

While the unconventional approach may result in plants that do not capture the full energy potential of sites, energy requirements—and the means to pay for energy—are likely to be modest in many remote rural communities. And although these plants may be less efficient and more prone to more frequent maintenance and earlier replacement, they are also more easily maintained and replaced then conventionally engineered plants built in such areas. Moreover, as energy requirements increase, plants built along the lines initially may be up-graded at a later time to capture more energy potential more efficiently.

III. Use considerations

The benefits arising from small hydropower projects are derived from its uses, in both quantitative and qualitative terms. Benefits are realized in different forms. Benefits from the producer's point of view may include:

- cost-savings in providing energy more cheaply than existing energy sources; and
- revenues from energy service to new loads.

Benefits from the consumer's point of view may include:

- cost-savings from reduced energy expenditures;
- additional cash income resulting from increased productivity and extended working hours;
- leisure income; and
- social benefits (comfort, convenience, security, prestige, etc.).

Benefits from the national point of view may include:

- greater reliability of energy supply;
- potentially fewer negative environmental impacts;
- potentially greater positive environmental impacts (erosion, deforestation, flood, and sedimentaion control); and
- foreign exchange savings.

Before moving to a discussion of how these benefits are considered in the economic analysis, some comments on the quantitative and qualitative nature of energy use from small hydropower plants are in order.

Capacity utilization

Capital costs are meaningless in determining the ultimate delivered cost of energy without first taking into account the degree to which the plant is used, economically speaking. Thus, unit energy costs will depend on two factors: capital costs and capacity utilization.

Capacity utilization of small hydropower plants is affected by water supply conditions and by demand conditions. Small rivers and streams in tropical areas frequently suffer from intermittent flows, due to the concentration of annual rainfall during wet seasons. Unless excess flow during these periods can be stored behind dams, operation of the plant during dry periods may be limited.

Even during periods when the plant may operate at full capacity, utilization may be constrained by irregularities in demand for energy. Load factors, which give the ratio of peak load to average load, are indicators of the nature of demand constraints for a given plant. Low load factors indicate the plant utilization is high only for very high periods, with much lower plant utilization during the majority of the time the plant is operated. Low load factors alone can have disastrous effects on the economic viability of small hydropower stations. Table 3 gives average load factors for five 200 kW plants installed in northern India during the 1970's. Assuming capital recovery over six years, the kWh costs for each plant vary considerably, even with a relatively small difference in load factor.

Table 3. Effect of load factors on generating cost (4)

Project	Average load factors (%)	Average kWh cost (cents)
Guptkashi	23.6	7.0
Genti-Cherra	20.3	8.3
Tilwara	22.3	10.1
Koti	10.7	27.5
Deoprayag	4.1	62.5

[a] Assumes full depreciation over 6 years.

From this example it is evident that small hydropower plants may not be economical in situations where utilization rates remain low and highly variable. Other energy solutions may be sought for such cases, such as the installation of diesel-driven generators. Figure 3 illustrates the conditions under which diesel generators offer a more cost-effective energy generation means than a similarly sized small hydropower plant. Cost-effectiveness for the hydro option increases as utilization rates increase, whereas the reverse is true for the diesel option. This is due to the low operating cost of hydropower systems since no fuel cost is involved. Fuel accounts for the majority of diesel energy costs, on the other hand, meaning that the diesel option is competitive only if utilization rates are low, below 20% in this analysis.

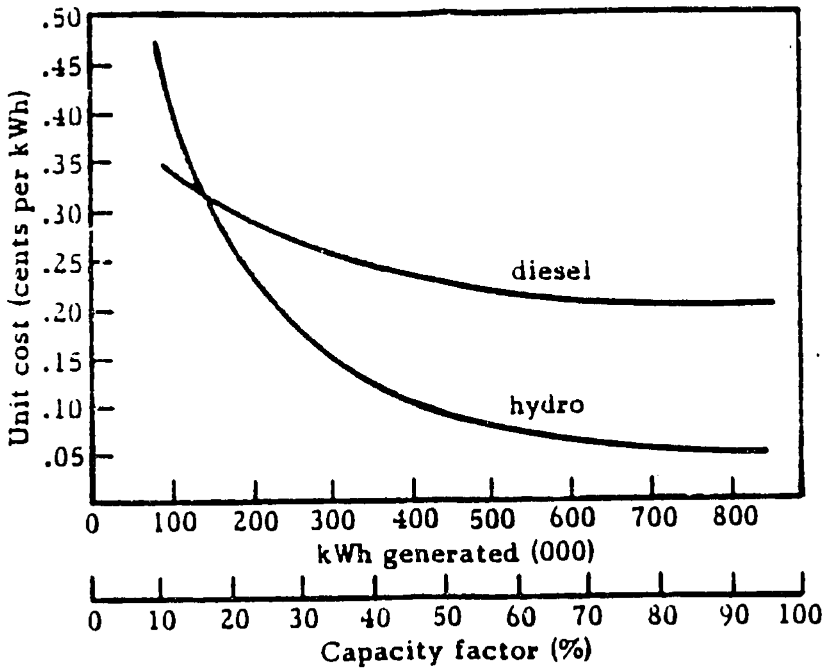

Fig. 3. Effect of capacity factor on unit cost of production (100 kW plant). Assumptions: hydro capital cost is $3,000 per kW; diesel capital cost is $450 per kW; annual O & M cost is 1.5% of capital cost for hydro, 4.5% for diesel; fuel cost for diesel is 18 cents per kWh; useful life is 30 years for hydro, 20 years for diesel; discount rate is 12%.

Supply and demand management

With all small hydropower projects, but particularly with small isolated plants, it is important to attempt to achieve a dynamic equilibrium between energy supply and the demand for energy. It has been seen how plants which are underutilized result in high energy costs. Two methods may be employed to minimize plant underutilization, one dealing with capacity (supply) planning, and one dealing with load (demand) management.

In the latter method, load leveling techniques are used to build up energy demand during off-peak periods, and reduce demand during times when energy requirements are normally high, such as evening hours and during mealtimes. Energy pricing policies may be used to penalize energy use during periods of normally high demand, and reward users of energy during times of low demand. Alternatively, more direct measures can be taken to level out loads on the plant. One measure is to develop means of storing energy during off-peak periods for use during peak times. Battery storage can be used in the case of low-level electrical applications. For uses requiring heat, such as cooking, electrical energy can be converted into heat by means of resistance coils, and then stored in an appropriate medium, such as insulated metal or stones. Another measure is to promote "productive" uses of energy during off-peak periods. Examples of productive end uses include irrigation pumps, foodstuff processing machinery, commercial appliances, and low-horsepower motors used in light rural industries. It has been NRECA's experience that promotion of productive uses such as these can have a considerable impact on the economic viability of rural electrification projects by raising energy demand and income growth in a community.

In the case of an isolated project, it is more difficult to approach a dynamic supply/demand equilibrium from a supply point of view, but not impossible. The objective on the supply side is to avoid investing prematurely in capacity which is not needed. In a 20-year or 30-year planning period, energy demand will most likely change dramatically over time. A community requiring 10 kW of capacity initially may need several hundred kW twenty years later. However the investment in a larger hydropower plant than is required for the first ten years or so could make the average cost of energy over the life of the project prohibitively high. One method of permitting incremental capacity growth is to build the plant in stages. For example, plants may be designed to operate with several turbines, which can be added over a period of several years. Alternatively, a very simple design can be used for the initial period which could be upgraded with more elaborate structures and equipment at a later date. Another incremental approach would involve the installation of a small diesel generator, having a much lower capital cost, to serve the community during the initial load-building years, which could then be replaced by the hydro plant when energy demand warrants the greater capital investment.

IV. Methodology for Prefeasibility Analysis

The methodology used for conducting economic prefeasibility analysis depends on the purpose of the energy project. Small hydropower projects can serve two objectives, from a supply point of view:

(1) to displace a more costly means of energy production; and
(2) to provide a new source of power.

In the first case, total project costs are compared with the cost of the alternative energy production means, where the benefits are equal to the cost-savings resulting from the provision of small hydropower to displace more costly energy. In the second case, total project costs are compared with benefits arising from the addition of new generating capacity, usually shown as revenues from the sale of energy. Projects may serve both objectives by reducing existing energy costs and providing additional capacity to serve greater energy demand.

An analysis must first be performed to assess whether the small hydropower investment offers a cost-effective means of supplying energy to serve a given amount of energy demand, stated as energy (kWh) production.

Cost-effectiveness

This level of analysis is a useful tool in screening projects as part of a regional or national survey of potential small hydropower sites. It is also an essential step in assessing the net benefits of small hydro projects whose primary purpose is to displace the higher cost of delivering energy by other, existing means. The most commonly used method to make this comparison is to find the present worth value of total life-cycle costs for each alternative. Costs, including capital costs and recurring costs, are entered in the years they occur. Total annual costs are then discounted to take into account the time-value of money.

The discounting process is needed to reflect the opportunity cost of capital, since the real value of an expenditure made in the future is less the real value of an equal expenditure made today. This is important in comparing the life-cycle costs of producing energy from hydro and diesel plants, since the majority of costs for the hydro project are made initially, while the costs of the diesel alternative are spread more evenly throughout the life of the project.

Recurring costs include operation and maintenance (O&M) costs and energy costs (with or without a real escalation factor). Inflation and the cost of money are already reflected in the discount rate, and thus are not needed, provided the discount rate selected approximates market interest rates. Equation (1) is the basic formula used in finding the total life-cycle cost in present worth terms.

$$\text{Total Cost} = CC + \sum_{n=1}^{L} \frac{O\&M_n + (E_n \times P_n)}{(1+r)^n}$$

where:

CC = capital cost

L = life of project

$O\&M_n$ = operation and maintenance cost in year n

E_n = unit energy cost ($/kWh) in year n

P_n = kWh production in year n

r = discount rate

Equation (1). Present worth cost calculation.

Capital cost in the case of the grid extension option includes the cost of extending transmission lines to the area to be served, and necessary transformer and protection equipment. Capital costs for the diesel alternative should be the average unit installed cost of diesel generators times the number of kW which the small hydropower plant would supply. It should be noted that diesel generators have a shorter lifespan than hydropower plants. Capital replacement for the diesel should therefore be shown every 5-15 years, depending on the average useful life period of such plants in the area.

Unit energy cost in the case of a diesel plant is the cost of diesel fuel to produce one kWh of energy. In the case of a grid extension option, it is the cost of producing (or purchasing) a kWh of energy on the grid.* This cost should be the long-term marginal cost of producing an additional unit of energy. Extension of the grid does not necessarily eliminate the need to invest in additional capacity, particularly in view of future load growth. The long-term marginal cost should therefore be based on demand studies which take into account additions to capacity that will be needed to serve the additional load over the duration of the period being studied. In the small hydro case, energy cost is zero, since there is no fuel cost. Escalation factors may be applied to the energy cost of both the diesel and grid options, to reflect real cost increases for fuel. A 2% escalation

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*In cases where the power is purchased from sources outside the country, this cost should be shown as the wholesale purchase price of electricity.

rate is generally used. To find the full annual energy cost for either option, the average kWh energy cost is multiplied by the annual kWh production assumed for the small hydropower plant.

O&M costs for the small hydro option are generally considered to be 1.5% of capital cost, except in the case of very small plants, where a more precise calculation should be made to reflect actual costs of an operator's salary, and minor maintenance and replacement costs.* O&M costs for the diesel option, requiring greater maintenance expenditures, is generally shown as 4.5% of capital cost. O&M cost for the grid option is zero, since these costs are already reflected in the long-term marginal cost of energy.

The study period over which total costs are calculated should be the expected useful life of the small hydro project. This period is frequently given as 30 years, although many plants operate twice as long, if properly maintained. For purposes of prefeasibility analysis, depreciation costs can be left out of the calculation.

Life-cycle costs are found by adding the total annual discounted costs for each option. The option giving the lowest total cost is the preferred investment strategy. If the small hydro option fails this preliminary test, it should be rejected. If the small hydro option offers a lower cost option than the diesel or grid options, then further analysis of the small hydro project may proceed.

Return on investment

The purpose of the cost-effectiveness analysis is to enable planners to achieve efficient resource allocation. In developing countries, political decisions are often made to provide electrical service to rural areas regardless of the net economic consequences of such a decision. The results of the cost-effectiveness analysis may therefore provide a basis for making investment decisions. This is not advisable, however, since benefit considerations have not yet been taken into account and may show that investments in alternative projects, such as transportation, would be more worthwhile. Needed, then, is a basis on which inter-sectoral resource allocation choices can be determined. Moreover, lending institutions generally require that further analysis be provided which examines the return on investment.

There are two economic indices used in determing the return on investment:

- benefit/cost ratio
- internal rate of return.

In each case, annual net cash flows are calculated by subtracting costs from benefits. Cost, benefit and net cash flows should be shown in both nominal and discounted terms for each year in the study period.

Benefit/cost ratio. This is a commonly used index to assess whether projects are economically feasible. The discounting process used in the cost-effectiveness analysis is also used here, only benefit flows are calculated as well. The comparison of total

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* For a 50 kW plant costing $2,000/kW installed, for example, total capital costs would be $100,000. Annual O&M costs would likely exceed 1.5% of this cost ($1,500).

present worth costs and benefits provides a ratio which indicates the economic attractiveness of a project. Equation (2) gives the economic formula used to derive benefit/cost ratios.

$$B/C = \frac{\sum_{n=1}^{L} \frac{B_n}{(1+r)^n}}{\sum_{n=1}^{L} \frac{C_n}{(1+r)^n}}$$

where:

B_n = Benefits in year n

C_n = Costs in year n

L = Life of project

r = discount rate

Equation (2). Benefit/cost calculation in present worth terms.

Projects with a benefit/cost ratio of less than 1 are considered unfeasible. Projects with a ratio of 1 or greater merit additional study to assess what rate of return is possible. This calculation is reviewed next.

Internal rate of return. To refine the assessment of net economic return on investment, the internal rate of return is calculated for the project. In the preceeding cashflow analysis, a discount rate is selected which represents the opportunity cost of capital. The purpose of this analysis is to find at what discount (interest) rate total costs and benefits are equal. Thus the undiscounted cashflows are used in this calculation. This interest rate, which represents the internal rate of return for the project, can be determined by trial and error in applying different discount rates to the cashflows until the correct value is found. Projects should have a internal rate of return exceeding the rate of return possible with other competing projects to be worth undertaking, strictly speaking. However if the project yields an internal rate of return approximating long-term market interest rates, the project is generally considered feasible.

It should be noted that the feasibility of projects as determined by the rate of return will depend considerably on the source of financing. Financing from private sources may require an internal rate of return of more than 20% for small hydropower projects, due to the high degree of financial risk that may be perceived with such projects. At the other extreme, where local communities may be able to raise their own resources to construct projects (possibly with government support) the rate of return may not be as important to the investment decision as non-financial considerations relating to the overall socio-economic development goals of the area. International development banks generally look for an internal rate of return of about 10%, although again, decisions to finance may also rely on how well the small hydropower, project complements other development projects and goals in the area.

Calculating project benefits

Although many direct and indirect benefits may be used to justify an investment on small hydropower, for purposes of prefeasibility analysis only benefits which can be represented in monetary terms are generally included, representing more of a financial than an economic analysis. Thus, certain long-term social and economic benefits such as education or health improvements, and the socio-political benefits resulting from the provision of electricity to new rural areas; and short-term benefits, such as increased productivity and security, are difficult to compute in monetary terms and are generally not included as specific benefits for prefeasibility analysis purposes. These benefits may be stated in qualitative terms, and could make a project with only a marginally attractive rate of return appear more worthwhile. Benefits which can be quantified more easily in monetary terms include cost-savings from the displacmenet of other energy sources and revenues from the sale of energy.

As mentioned at the beginning of this section, small hydro projects may serve the function of reducing existing energy costs or providing a source of energy to serve new and additional energy needs. A second distinction is also needed in defining the basis for calculating economic benefits, from a demand point of view; a distinction between plants which are interconnected with a transmission grid and those serving an isolated load.

With grid-connected projects, benefit calculations for purposes of prefeasibility analysis are relatively simple. Annual benefits for hydropower projects in the lower capacity range are generally equal to total cash savings from the displacement of other more expensive energy production serving the grid. For these projects, assuming the transmission network covers a sufficiently large demand area, the basis for calculating these benefits is the annual kWh production capability of the plant. More detailed analysis of daily and annual load characteristics on the grid system at the full feasibility stage may show that demand fluctuations prevent full absorption of the plant's generating capability, particularly during off-peak periods when the base load may be served by cheaper means (e.g. large hydropower).

In conducting prefeasibility analysis of isolated projects, demand analysis becomes more important. Benefits in the form of cash savings and revenues are based not on the estimated output, but on estimated demand.* Since loads are likely to be variable, and possibly quite low, assumptions for sale of power and energy displacement must be fairly carefully defined by estimating the nature of energy demand for specific categories of consumers, or specific end uses.

Small isolated projects serving new loads may also present special problems in quantifying benefits, since in some cases revenues - representing to some degree the economic value of the energy - are either not collected or are based on tariff schedules substantially below the economic value of the energy provided. To allow a more complete assessment of economic benefits, a measure of the willingness of users to pay for the energy provided may be surveyed by estimating the user's existing energy costs, the resulting increase in productivity, and the higher quality of life which is attributable to the energy (5).

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* A general review of demand analysis is provided in Jackson & Lawrence, "Electrical Distribution and End Uses for Isolated Systems."

Finally, demand for energy is likely to change over time. To account for this, one or more escalation factors may be applied to annual benefit totals to reflect demand growth. As a general rule, demand growth in newly electrified areas averages 5-10% a year, except in the early years of operation when initial consumer build-up may yield a higher growth rate. Moreover, energy production estimates should also take into account the possibility of grid interconnection during the life of the project, at which time excess energy could be fed to other demand centers. Benefit calculations for years following interconnection may therefore increase. In the same vein, annual cost calculations may be lower during the initial years of a project, if it can be built in stages to accomodate greater loads on the system, including additional loads resulting from grid interconnection.

Sensitivity analysis

Life-cycle costs, benefit/cost ratios, and internal rates of return may vary considerably when assumptions are changed. Since it is hard to predict certain conditions, such as diesel fuel costs and demand for energy, sensitivity calculations may be made to see if the net value of projects remain favorable under different conditions. Certain assumptions in the baseline calculation should be changed to reflect, for example, higher discount rates, hydro capital costs, fuel costs, and different rates of energy demand growth. The results of these calculations can help to ascertain the degree of risk involved in a project, and how durable the project's economics are under more adverse conditions.

V. Conclusion

The process of identifying economically feasible projects cannot be divorced from the larger macro-economic context in which the projects are being considered. Issues pertaining to the country's power sector program and the overall development plan of the area will have an important bearing on the desirability of specific small hydropower projects. Moreover, capital is scarce in many developing countries, particularly capital which is available in hard currencies. Small hydropower projects are relatively capital-intensive and thus should undergo rigorous examination at the full feasibility stage to ensure that the capital resources of the country are efficiently allocated. Shadow pricing of the major elements of a project should be applied to assign the real economic value, for example, of labor and foreign exchange. Similarly, the discount rate should be sufficiently high to reflect the real value of capital to the society as a whole.

In view of the scarcity of foreign capital, full advantage should be taken of opportunities to utilize locally available resources. Above all, the ultimate value of projects will depend on the uses of the energy produced. Productive uses of electrical energy yield multiplier effects to a project which are greater than those associated with uses to provide greater convenience or a more pleasant lifestyle. While these uses are certainly desirable, the rural poor may not be able to afford the luxury of energy expenditures for such ends. Productive uses, on the other hand, mean increased employment opportunities, higher output levels, and additional income to a community. Planners and administrators, therefore, should not overlook the need to incorporate productive uses in any project to provide electricity to rural areas.

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