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The Economics of Renewable Energy Systems for Developing Countries

by: David French

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FOR DEVELOPING COUNTRIES

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Washington, D.C. — January 1979

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ABSTRACT

In many parts of the Third World, projects are being developed to test such renewable energy systems as solar pumps, biogas plants, and solar cell arrays to power pumps and grinders. Virtually nowhere, however, has adequate work yet been done to determine if these systems are worth their costs.

This report outlines the benefit-cost techniques which allow systems to be evaluated from the standpoint of individual buyers (financial analysis) and the society as a whole (economic analysis). Special attention is given to problems of particular importance in reviewing energy systems: local measurement of costs and benefits, determination of investors' discount rates, shadow-pricing, allowance for social costs, and so on.

Detailed benefit-cost analyses are provided for three representative systems:

- a 40-hp solar thermal irrigation pump near Bakel, Senegal;

- a family-scale Indian biogas plant;

- a 5.5 kw solar cell irrigation pump on the borders of Lake Chad.

In each case, consideration is given to whether these systems would be equally (un)appealing in other places or under other assumptions as to capital costs, the price of conventional fuels, or other variables.

Neither the solar thermal pump nor the family-scale biogas plant appears to be profitable in either financial or economic terms under any plausible sets of assumptions. The solar cell pump has positive net benefits by economic (if not financial) measures, but is unlikely to be competitive with diesel power for another decade. None of these systems, in other words, shows any immediate promise for significant developmental applications; barring the unforeseen, only solar cell arrays offer promise for the relatively distant future.

At best, some of these devices might ultimately become competitive with expensive commercial energy. Such devices will therefore be of interest first to people now using substantial amounts of such energy--that is, the relatively rich. Only much later might significant benefits begin to filter down to the poor.

Given these findings, organizations concerned with the poor might well give renewed attention to meeting basic energy needs through less sophisticated systems: village woodlots, improved wood stoves, hand or pedal pumps and grinders, hydraulic ram pumps, etc. By finding systems whose benefits are commensurate with their costs, and whose costs are within reach of the poor, it may be possible to provide more energy to the people most in need of it.

TABLE OF CONTENTS

Page

INTRODUCTION

In many parts of the Third World, projects are now being
designed to test renewable energy systems: biogas plants,
improved wood stoves, solar cell arrays for powering pumps
or grinders, and so on. Often, a foreign assistance agency
pays for the systems and supports field testing to determine
their performance under "real" conditions.

To date, in virtually none of these projects has adequate
consideration been given to whether systems being tried are
worth their cost. This may not matter as long as outsiders
are footing the bill. To reach beyond an experimental popu-
lation, however, renewable energy devices will have to be
purchased by individuals, groups, or local agencies which
are likely to be more discriminating in spending their money.
As yet, we have little basis for guessing whether new systems
will offer respectable returns from the point of view of
these ultimate buyers.

Of course, the allure of new technologies will finally
be determined only as widespread attempts are made actually
to market them. Nonetheless, thought about the economics
of these systems should begin much earlier. Even preliminary
economic analysis of particular applications may strongly
suggest that some devices be discarded and others stressed,
a conclusion worth hearing before elaborate field tests are
arranged. Where tests are then carried out, they should be
carefully structured to provide even better economic infor-
mation. If the data which result promise broad economic
appeal for given systems, serious thought can be given to
ways of introducing these systems more generally.

The following sections show how benefit-cost analyses of
renewable energy devices are carried out. Sections I and II
cover basis analytical issues from the perspective of indiv-
idual investors (financial analysis) and of society as a whole
(economic analysis). Sections III, IV, and V use "real-world"
data to investigate representative energy devices in specific
places. Section VI draws general conclusions about renewable
energy systems and the use of benefit-cost techniques in their
evaluation.

I. FINANCIAL ANALYSIS OF RENEWABLE ENERGY PROJECTS

A. Benefit-Cost Techniques*

Financial analysis of a given project is carried out from the perspective of the person (or private group) considering investment in the activity. For example, financial analysis might show how a farm family would weigh purchase of a solar cell pump to provide irrigation water for food production. "Benefits" would consist of the additional food grown; "costs" would be the expenses of growing it.

Note that we would not try to analyze the pump in isolation from the family's irrigation project as a whole. Crops will not spring up simply because a pump is installed at the edge of a river. To grow food requires many other inputs as well: land must be prepared and irrigation channels dug; workers must be found; seed and fertilizer must be bought. Only by looking at the entire complex of benefits and costs associated with the functioning of the pump can we assess its financial value.

In principle, such assessments are quite straightforward. We begin by estimating benefits and costs for each year of the project's lifetime, generally defined as the period before major capital equipment is expected to wear out. By subtracting costs from benefits, each year's "net financial benefits" can be found. Figures for net benefits are then manipulated as shown in the following pages to judge the financial appeal of the project to prospective buyers of the pump.

Special care needs to be taken to show the actual timing of costs and benefits. In the case of our solar cell pumping scheme, for example, heavy costs (purchase of pump and fertilizer, labor for planting) are incurred at the outset of the project. Benefits of the first crop (sale and consumption of food) follow months later. To lump all these events together in a single "Year 1" would be to suggest that they happen more or less simultaneously, an assumption that would lead us to overestimate the project's attractiveness. More accurately to indicate lags between costs and benefits in this instance, we might

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*For general discussions of benefit-cost techniques, see J.P. GITTINGER, 1972; W. JONES (ed.), 1975; I. LITTLE and J. Mirrlees, 1974; H. SCHWARTZ and R. Berney (eds.), 1977; S. PAK and C. Taylor, 1976; L. SQUIRE and H. van der Tak, 1975; UNIDO, 1972. Complete citations for these and other publications are provided in the Annotated Bibliography.

wish to show initial investment and the first planting in the project's "Year 1," harvesting of the first crop (and planting of the second) in "Year 2," and so on.*

As the basis for financial analysis of this imaginary pumping project, we can now make the following assumptions:

- The pump, which in local currency costs 100 pounds (₤100), will be purchased in Year 1 and will wear out at the end of Year 6. No maintenance of the pump is required.

- Labor to work the irrigated land will cost ₤10 for planting in Year 1, ₤20 for harvesting and planting in Years 2-5, and ₤10 for harvesting in Year 6.

- "Physical inputs" in the form of imported fertilizer applied during planting will cost ₤10 in Years 1-5.

- Land irrigated by the pump will produce an extra ₤80 worth of food each year, ₤50 for sale and ₤30 for consumption by the farmers themselves.

Net financial benefits are then determined for each year of the project, as shown in Table 1. We must now decide whether the

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Table 1: Net Financial Benefits of Solar Cell Pump Project

	Year					
	1	2	3	4	5	6
Benefits						
Sales of additional food grown	0	50	50	50	50	50
Additional subsistence production	0	30	30	30	30	30
- Costs						
Capital equipment (pump)	100	0	0	0	0	0
Physical inputs (fertilizer)	10	10	10	10	10	0
Labor	10	20	20	20	20	10
= Net Financial Benefits	-120	50	50	50	50	70

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*- For a more complete discussion of ways to deal with phasing of costs and benefits, see W. SCHAEFER-KEHNERT, 1978a.

Ƀ270 in net benefits spread over Years 2-6 will be viewed by
the farmer as adequate compensation for the Ƀ120 in net costs
incurred in Year 1. At issue here is the fact that money
delivered in the future is worth less than the same amount of
money in hand today. Moreover, the longer it takes to get
future money, the more we "discount" its value to us now.
In the case of the pump, the Ƀ50 projected in net benefits
for Year 5 will therefore weigh much less heavily than the Ƀ50
promised for next year as the farmer considers whether or not
to buy the system.

Mathematically, we determine the value to an investor now
of promised future income by multiplying each year's benefits
by the appropriate "discount factor." At an annual rate of 30%,
for example, discount factors are .769 for Year 1, .592 for
Year 2, and so on.* Here, we are assuming that each pound (Ƀ)
promised at the end cf this year is of the same value to the
investor as Ƀ.769 now; a pound two years from now is worth
Ƀ.592 today; etc.

We can now choose either of two measures--net present value
or internal rate of return--to decide whether the pump project
is worthwhile. U.S. AID and the World Bank both prefer to
find internal rates of return, but judgments as to a project's
value will be essentially the same whichever measure is applied:

- **Net Present Value**: Assuming a discount rate of 30%,
  we consult standard tables to find the discount factor
  applicable to each year's benefits. The present value
  of benefits can then be calculated, as shown in Table 2.

Table 2: **Present Value of Benefits, Solar Cell Pump Project**

		Year					
		1	**2**	**3**	**4**	**5**	**6**
Net Benefits	(From Table 1)	- 120	50	50	50	50	70
X Discount Factor (30%)		.769	.592	.455	.350	.269	.207
= Present Value of Benefits		- 92.3	29.6	22.8	17.5	13.5	14.5

NET PRESENT VALUE = Ƀ5.6; INTERNAL RATE OF RETURN = 33%

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*- Tables of discount factors at various discount rates are
  included, e.g., in J.P. GITTINGER, 1972 (Appendix) and
  1973. See also page 68, "Discount Factors," below. A rate
  of 30% is assumed here in line with the discussion of
  investors' discount rates in Section I.B.3, below.

By adding together the present value of benefits for
all five years, we discover that total <u>Net Present Value</u>
of the project is Ł 5.6. Since any project with a net
present value greater than zero is assumed to be economically
sound, it would be in the farmer's interest to go ahead
and buy the pump.

- <u>Internal Rate of Return</u>: Alternatively, we can find a
  project's annual rate of return to the resources the
  farmer must commit to it. We do this by experimenting
  with various discount rates until we find one which
  yields a net present value of zero.* This is the
  project's <u>Internal Rate of Return</u>, which in the case
  of the pump is 33%. The rule here is to implement
  projects having an internal rate of return greater
  than the discount rate used for project evaluation.
  Since we here have assumed the appropriate discount
  rate to be 30%, the pump again appears to be econom-
  ically sound.

B. Issues in Financial Analysis

Major issues in financial analysis include the evaluation
of project benefits and costs, estimates of buyers' discount
rates, ways of accounting for risk and uncertainty, and the
availability of credit.

1. <u>Measuring Benefits</u>. In our solar cell pump example,
we assume that the project will irrigate land for food produc-
tion. Project benefits therefore consist of the extra food
grown, beyond what would have been produced in the pump's ab-
sence. This added production is valued at its market price,
whether sold or eaten on the farm, giving us a simple measure
of each year's total benefits.

For many renewable energy systems, however, benefits will
be more difficult to calculate. Suppose, for example, that
our project had been designed to pump drinking water from a
new well, relieving village women from their traditional obli-
gation to haul water from distant streams. In an analogous
case, the construction of biogas systems for cooking, a primary
result would be to free women and children from the need to
collect firewood. Although project benefits in both instances
consist of labor time saved, it is not immediately clear what
value should be attached to these savings.

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*- Further guidance on how to do these calculations is provided
   in W. SCHAEFER-KEHNERT, 1978b.

In some such cases, benefits could be inferred from other information. If commercial sales of firewood prevailed in nearby areas, for example, the market price of the wood could be used as an approximation of its value in our biogas village. Benefits of the biogas cooking project would then be equivalent to the imputed value of wood which no longer would need to be gathered.

Lacking such data, we would have to estimate benefits in terms of new activities in which women and children could now take part. If there were no productive use for the time freed from collecting wood or water, benefits of the biogas or pumping system would equal the monetary value attached locally to leisure. Although this value is something at which we can probably only guess, it is likely to be quite low. On the other hand, if paid employment were readily available to occupy this time, project benefits would equal the new wages received.

Unfortunately, reality tends to be even more complex. In practice, people are likely to use time freed from old chores to engage in a variety of activities: vegetable gardening (benefits equal to the market value of produce grown); additional child care or more careful food preparation (benefits positive but difficult to quantify); relaxing (meager financial benefits); and so on. Only after deciding which blend of activities will probably be chosen can we determine the nature and level of project benefits.

2. **Measuring Costs.** Much less mystery attaches to the measurement of project costs, most of which are relatively straightforward. Care should be given, however, to ensuring that important costs are not simply ignored. For example, some analyses fail to account for work required of buyers in terms of site preparation or installation of new energy systems. Such work should be included among project costs at wage rates reflecting the value which buyers attach to their labor. As a first approximation of reality, we might assume that this value would be somewhere between 50% and 100% of the prevailing local wage for equivalent work.

Also important is to include costs of equipment needed to use a new kind of energy. If methane gas becomes available for cooking, people will have to buy gas stoves and new utensils. To use the slurry from the digester for fertilizer, people will need containers and some way of moving these to distant fields. Stove, utensil, container and cart must all be included as project costs.

Provision must also be made for the recurrent costs of tending to a device, net of labor costs which the device may eliminate. A biogas digester, for example, will require people to collect and haul both dung and water to a central point, in addition to overseeing the system's functioning and distributing the slurry it produces. Some of this work, however, might be done during time formerly spent gathering firewood, if biogas were to replace wood for cooking. The project's net labor costs would therefore consist of work required for operating the system, less time freed from collecting wood.

Similarly, it is important to account carefully for raw material costs. In biogas systems, dung is transformed into gas for cooking and slurry for fertilizer, both of which are project benefits. In traditional practice, however, dung may already be burned for fuel or left directly on the ground as fertilizer. If the owner of the biogas system foregoes these benefits to feed a new digester, the fuel or fertilizer value of the dung in its unprocessed form should be considered a project cost.

3. **Determining Investors' Discount Rates.** Analyses of energy projects sometimes assume that potential investors will apply a discount rate of 10% to future benefits in deciding whether or not to invest in energy systems. That is, buyers would believe that a pound in hand today is more or less interchangeable with ₤1.1 in hand a year from now, ₤1.21 in two years, and so on. This 10% figure is selected largely because it is a "round" number somewhere within the range of discount rates that people in modern economic sectors apply to their investments.

In thinking about renewable energy systems for the poor, however, we are concerned with people who are not part of the modern world economy. For an impoverished villager, a year from now is very far away. Consciousness must be focused on a present in which the margins for survival are extremely narrow. To part with a pound today is a major act, one which is not adequately compensated by providing one-tenth of a pound in interest sometime next year. Clearly, the poor of the world will apply a discount rate to future benefits which is well above our own.

Economic theory suggests that discount rates in a given area are roughly equivalent to interest rates on local loans. Outside of urban areas, the applicable rate would be that charged by unsubsidized sources of agricultural credit. Following a worldwide study of such credit, the World Bank (1975a, pp. 29, 79) found that interest rates averaged more than 32% in real terms. As a first approximation of reality, we might therefore assume that most people in rural areas will apply a discount rate of at least 30% in considering new investments.

This rate is likely to be highly variable in practice. Expressed as national averages, the World Bank data show commercial interest rates for agricultural credit reaching as high as 192%, although most countries fall in the 20-66% range. Within a given country, moreover, rates may vary by region and by income group. For financial analysis of our imaginary solar cell pump, we have assumed we are operating in an "average" rural area and have used a discount rate of 30%. In crude accord with different local realities, Sections IV and V use discount rates of 15% for India and 50% for Chad.

4. <u>Risk and Uncertainty</u>. As indicated in Table 2, above, our pump project has a net present value of ₺5.6 and an internal rate of return of 33%. These are at least marginally acceptable results--on the assumption we can be sure of our numbers. Unfortunately, we are not omniscient. Potential buyers are likely to view the analysis in Table 2 as reflecting only one of several conceivable outcomes, including the possibility of serious financial loss. We need to account for this sense of uncertainty and risk before making final guesses about the pump's financial attractiveness.

In the language of project evaluation, we use "sensitivity analysis" to help explore more fully the implications o
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 ertainty.* Essentially, this requires us to calculate alt native returns to the project according to the assumptions investors may make about possible outcomes of important variables. If a project's net present value remains positive even after the least favorable numbers are assigned to all these variables, the activity will be worth carrying out under any plausible conditions.

Often, however, sensitivity analysis will suggest a range of possible returns, from positive to negative. In our pump project, for example, to add the assumption that ₺5 in annual maintenance will be required in Years 2-5 reduces net present value from ₺5.6 to -₺2.8. Alternatively, an additional ₺10 in annual food production would increase NPV from ₺5.6 to ₺24.2. Revised assumptions about future costs of fertilizer or labor would also influence returns to the project.

For many small-scale energy projects, the most important uncertainties relate to our guesses as to the life span of capital equipment. We have assumed, for example, that our pump

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*- A discussion of these issues appears in I. SIRKEN, 1975.

will wear out in Year 6, yielding an NPV of Ł5.6. Returns, however, are extremely sensitive to alternative assumptions. If the pump lasts two years longer, NPV will jump to Ł18.0; if the pump wears out two years earlier, NPV will plummet to -Ł15.4.

Having calculated these alternative NPVs, we must now estimate how likely each is to occur in reality. In doing this, we must be especially careful not to let our expectations diverge from those of potential investors. Outside analysts, for example, commonly overestimate the life span of capital equipment to be used in rural areas. Inhabitants of these areas, on the other hand, may be quite conservative in their expectations of untried systems. If such tendencies are ignored, we may badly misrepresent the attitude which villagers will take toward the systems under review.

Assuming we can tell what probabilities are attached to various project outcomes, we are left to decide how buyers will use this information to make investment decisions. Given the data provided above, for example, will people buy our pump if there are equal chances of its lasting until Year 4, Year 6, or Year 8? Unfortunately, at this point we must turn from theory to intuition. So far, nobody has been able to provide convincing models of how buyers will actually behave under given conditions of risk and uncertainty.*

Students of these problems do agree that the poor seem more "risk-averse" than the rich, allowing us to conclude that projects stand a fair chance of being rejected if they involve any real possibility of substantial loss. This may be true even of projects which to us seem "acceptably" risky, with a strong probability of gain. Since our pump project offers equal chances of comfortable profit, marginal profit, and considerable loss, poor farmers might well regard it with a certain lack of enthusiasm.

Although we often will be unable to design a project which is "objectively" risk-free, there are steps we can take to make a given degree of risk more acceptable. According to a paper on small farmer risk-taking by Development Alternatives, Inc. (1976), risk-aversion is minimized where new techniques are closely related to familiar ones, farmers are expected to contribute labor rather than cash to the project, cooperation among farmers is encouraged, and dependence on outsiders is avoided. Without knowing more about how a solar cell pump might actually be introduced, it is difficult to know whether our irrigation project could be adjusted to meet these conditions.

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*- On the state of the art, see S. BERRY, 1977; DEVELOPMENT ALTERNATIVES, Inc., 1976; J. ROUMASSET, 1977.

5. Credit. The availability of unsubsidized credit through the local capital market will not greatly affect the attractiveness of a project. Since we assume that investors' discount rates are equivalent to local interest rates, loan repayments (including interest) will automatically be discounted to a total present value equal to the amount of the loan itself. With or without the loan, in other words, the project's net present value to the investor will be the same.

This can be seen in Table 3, where we assume that a loan of ᵬ100 is made available in Year 1 to cover the full cost of

Table 3: Financial Analysis, Solar Cell Pump Project (Assuming Unsubsidized Credit)

			Year			
Benefits	1	2	3	4	5	6
Sales of additional food grown	0	50	50	50	50	50
Additional subsistence production	0	30	30	30	30	30
Loan	100	0	0	0	0	0
- Costs						
Pump	100	0	0	0	0	0
Fertilizer	10	10	10	10	10	0
Labor	10	20	20	20	20	10
Loan repayment*	0	41	41	41	41	41
= Net Financial Benefits	-20	9	9	9	9	29
x Discount Factor (30%)	.769	.592	.455	.350	.269	.207
= Present Value of Benefits	-15.4	5.3	4.1	3.2	2.4	6.0

NET PRESENT VALUE = ᵬ5.6; INTERNAL RATE OF RETURN = 45%

*Based on a capital recovery factor of 0.41 for a loan to be repaid in five equal installments at 30% interest (J. GITTINGER, 1973, p. 61).

the solar cell pump. The loan is repaid in equal installments over Years 2-6 at the local interest rate of 30%. Other benefits and costs are unchanged. Under these conditions, the project has a net present value of ₺5.6. This is identical to the NPV calculated in Table 2, where no credit was assumed to be available.

Although NPV is not affected by the provision of unsubsidized credit, the project's internal rate of return rises from 33% to 45%. This is a result of the financial "leverage" which buyers achieve as they invest less of their own capital in the activity. Since the investor's chances of actually gaining or losing cash are exactly the same regardless of the change in IRR, however, this increase is unlikely to have any dramatic impact on the farmer's interest in the system.*

While credit may not alter a project's intrinsic appeal, loans can make it more likely that an appealing project will actually be carried out. A farmer who found our irrigation scheme to be of great interest, for example, might lack the ready cash to buy the pump. In this case, a loan would allow the investment to be made out of farm income over the project's lifetime. At an unsubsidized interest rate of 30%, credit here does not make the investment more attractive; it simply makes it possible.

In practice, government agencies in developing countries provide rural credit for selected purposes at average interest rates of close to 3%, corrected for inflation. (WORLD BANK, 1975a, p. 46.) Given credit on these terms, our solar pump project would become extremely attractive to poor farmers. (Given credit on these terms, almost any investment would become extremely attractive to poor farmers.) Since heavy government subsidies are implied by loans of this sort, however, the question immediately arises as to whether the solar cell pump is valuable enough to society as a whole to warrant such support. The analytical procedures required to answer this question are the subject of Section II.

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*— On this point, see W. SCHAEFER-KEHNERT, 1978c. Material on agricultural credit can be found in D. ADAMS, 1977; OHIO STATE UNIVERSITY, 1972, 1976, 1977.

II. ECONOMIC ANALYSIS OF RENEWABLE ENERGY PROJECTS

Where "financial" analysis adopts the perspective of the potential buyer of a system, "economic" analysis considers the system's value from the point of view of society as a whole. Major adjustments required to reflect this broader outlook include shadow pricing, the calculation of social costs and benefits, and consideration of secondary effects.

A. Shadow Prices

Investors must live with the prices they confront in the market. Such prices, however, may be distorted by monopoly powers or other forces to the point that they only poorly reflect underlying economic conditions. To take account of these conditions, governments will wish to use "shadow" prices in calculating returns to the project from the national perspective. The need for shadow pricing arises most commonly in terms of internationally traded goods, labor costs, and discount rates.

1. _Traded Goods_. Many developing countries arbitrarily fix exchange rates at levels which overstate the buying power of their currencies in world trade. One result is to make imported goods appear unrealistically cheap, a situation reflected in the need for import controls to avoid massive balance-of-payments deficits. In analyzing development projects under these conditions, planners will first estimate the exchange rate which would exist if a free market prevailed. Imports are then valued according to this "shadow" rate, increasing their cost for the purposes of economic analysis.

2. _Labor Costs_. The "shadow" wage expresses the cost to the economy of diverting labor from its present occupations to the new project. Since the unskilled laborers who will work on our energy project are likely now to be underemployed, their shadow wage might range from zero (assuming no other available work) to perhaps half of the market wage (assuming they might otherwise be employed half-time elsewhere). In general, skilled workers will already be fully employed; their shadow wage is therefore equivalent to their market wage.

3. _Discount Rates_. In theory, economic discount rates should approximate the interest rate at which all capital in the economy would be invested under perfectly competitive conditions. Some would argue that this rate should be adjusted downward to reflect the preference of "society," as opposed to

individuals, for future growth rather than present benefits.
In either case, the proper rate will appear nowhere in the
market: rural interest rates will be far too high, for
example, and prime lending rates too low. According to J.
Price Gittinger, "In practice, the [economic discount] rate
chosen is simply a rule of thumb: 12 percent seems to be
a popular choice. . ." (1972, p. 90.)

    4. Application to Pump Project. To shadow price our
pump project will require a number of adjustments in the data
provided for financial analysis in Tables 1 and 2. If we assume
that the shadow price of foreign exchange is 20% greater than
official rates, the cost of imported capital equipment will
rise from Ƀ100 to Ƀ120 and the cost of imported fertilizer
from Ƀ10 to Ƀ12. Assuming that limited alternative employment
is available for unskilled laborers, we might use a shadow
wage half that of the wage actually paid by investors. And
in line with the "popular choice" of project analysts, we will
use a shadow discount rate of 12%, as opposed to the financially
applicable rate of 30%.

    Given these shadow prices for traded goods, labor, and
capital, economic data for the pump project will be as out-
lined in Table 4. Because of the much lower discount rate,

Table 4: Economic Analysis, Solar Cell Pump Project
(changes from Tables 1 and 2 indicated by *)

	Year 1	2	3	4	5	6
Benefits						
Sales of additional food grown	0	50	50	50	50	50
Additional subsistence production	0	30	30	30	30	30
- Costs						
Capital equipment (pump)*	120	0	0	0	0	0
Physical inputs (fertilizer)*	12	12	12	12	12	0
Labor*	5	10	10	10	10	5
= Net Benefits	-137	58	58	58	58	75
X Discount Factor (12%)*	.893	.797	.712	.636	.567	.507
= Present Value of Benefits	-122.3	46.2	41.3	36.9	32.9	38.0

NET PRESENT VALUE = Ƀ73.0; INTERNAL RATE OF RETURN = 33%

the project's net present value has jumped from ₤5.6
(by financial measures) to ₤73.0. By chance, the project's
internal rate of return remains the same, 33%. Since we
are comparing this with a discount rate of only 12%, however,
the project so far seems more appealing on national economic
grounds than it did from the financial perspective of the
individual investor.

B. Social Costs and Benefits

     As a next step in economic analysis of the pump project,
we must account for "social" costs and benefits. These are
items which need not be considered by the private investor,
but which have impact on the economy as a whole. Where
energy systems are concerned, social costs will often spring
from the need for extension services or the diversion of renew-
able resources from existing uses. Social benefits might
include positive changes in the environment.

     1. Extension Services. In promoting use of a new energy
system, governments may have to carry out a number of functions.
Prominent among these could be telling people that the system
exists, training them in its use and maintenance, providing
technical advice during the life of the project, and evaluating
results. Such activities, which we lump together here as
"extension services," do not involve costs to investors and
are therefore ignored in making financial calculations. Since
these services do represent costs to the society as a whole,
on the other hand, they are included in economic analysis.

     2. Diversion of Resources. Raw materials which are
"free" from the investor's point of view may have costs when
viewed from a broader perspective. If the owner of a biogas
system collects dung from village streets, for example, these
resources are "free" for the purposes of financial analysis.
To the villagers who formerly used this dung for fuel, how-
ever, there are definite costs involved. Since economic
analysis considers a project's impact on the society as a whole,
the fuel value of the dung as traditionally burned is considered
an economic cost of the biogas system. Comparable problems
could arise in evaluating devices using such renewable resources
as wood or water.

     3. Environmental Impact. Many renewable energy projects
will have positive environmental consequences. This is most
vividly true of projects which reduce the need for firewood.
Since governments may ultimately have to replant woodlands

stripped of their wood, the value of trees left uncut due to an energy project should be considered a project benefit. Analogous benefits might follow from an irrigation project allowing cultivation of bare land which would otherwise be left to erode.

4. Application to Pump Project. Adjustments of this sort could affect our solar cell pump project in various ways. Assume, for example, that extension services will add costs of Ь30 in the first year and Ь10 in subsequent years (Ь5 in Year 6). In preempting the village well for irrigation, the pump might increase the need for women to haul drinking water from more distant points, adding an extra Ь10 (shadow wage) in labor costs for this purpose over the life of the project. Finally, if a process of erosion is reversed through irrigation of new cropland, the government might add Ь50 in estimated benefits to reflect soil stabilization costs it would have had to meet in the project's absence.

In economic terms, the project now appears as shown in Table 5. Net present value falls somewhat, but only to Ь35.2.

Table 5: Revised Economic Analysis, Pump Project
(changes from Table 4 indicated by *)

	Year					
	1	2	3	4	5	6
Benefits						
Sales of additional food grown	0	50	50	50	50	50
Additional subsistence production	0	30	30	30	30	30
Lower soil stabilization costs*	0	0	0	0	0	50
− Costs						
Capital equipment (pump)	120	0	0	0	0	0
Physical inputs (fertilizer)	12	12	12	12	12	0
Labor	5	10	10	10	10	5
Extension services*	30	10	10	10	10	5
Extra water hauling*	1	2	2	2	2	1
= Net Benefits	−168	46	46	46	46	119
X Discount Factor (12%)	.893	.797	.712	.636	.567	.507
= Present Value of Benefits	−150.0	36.7	32.8	29.3	26.1	60.3

NET PRESENT VALUE = Ь35.2; INTERNAL RATE OF RETURN = 20%

The project's internal rate of return is 20%. By standard
tests of economic soundness, in other words, the project
seems relatively attractive.

C. Secondary Effects

In addition to carrying out their primary functions
(pumping water, cooking food, grinding grain), new energy
systems may have indirect effects on an area's capacity for
further development. Since the real concern of economic
planners is "development," not simply the performance of
narrowly-defined tasks, there is need to allow for these
indirect effects as decisions are made about energy systems.
This is especially important since the effects can vary
considerably depending on the specific device chosen to
do a given job.

To illustrate, suppose we are offered the choice between
pumping systems run by "pedal power" or solar cell electricity.
Even if these have similar economic returns, secondary effects
may sharply differ. For example, the pedal pump could call
forth a local capacity to make, assemble, and repair impor-
tant parts. In addition to representing new business oppor-
tunities in itself, this process could engender new skills
which would be applicable to other development activities.
The more complex solar cell pump, on the other hand, would be
largely imported and would probably demand maintenance skills
well beyond what local artisans could be expected to provide.
In contrast to the pedal-driven system, it is at least
plausible that the solar cell pump might therefore do its job
without advancing much the cause of local development.

Secondary effects are more complex than this, of course,
and they represent only one aspect of project analysis. None-
theless, this line of inquiry raises questions as to whether
the total impact of our solar cell pump would justify the
heavy government support which its widespread use might require.
Given the information we have invented here, it seems impossible
to come to any final judgment about the value of our imaginary
project. In the sections which follow, we turn to more real-
istic data in hopes of finding actual systems about which more
can be said.

III. BAKEL (SENEGAL) SOLAR PUMP

A. The System

In late 1979, a solar thermal irrigation pump will be installed near the town of Bakel on the Senegal River. The Bakel pump is a 40 HP system relying on energy absorbed by 20,000 square feet of flat-plate solar collectors. By circulating water through pipes running between the collectors and a boiler, the system carries heat to the boiler. Freon circulating separately through the boiler absorbs the heat and is vaporized. The expanding Freon drives a turbine which powers the pump.*

The Bakel system is being manufactured jointly by Thermo Electron Corporation and by SOFRETES, a French firm with extensive experience as a builder of solar pumps. Cost of the Bakel unit is $1.25 million, installed, although the manufacturers estimate that comparable units would be only $900,000 each if at least ten could be made at a time. At the latter price, cost of the system is $30,000/kw, compared with $25,000-$62,500/kw for other designs currently available. (J. WALTON, 1978, p. 17.)

B. The Project

The solar pump will be tested within an existing irrigated agriculture scheme, which is scheduled to cover 1900 hectares in the area around Bakel, Senegal. At full capacity, the solar pump will provide water for a 200-hectare section of this land. In accord with the design for the original project, small diesel pumps will be used to irrigate the remaining 1700 hectares. Emphasis will be on rice production, although small quantities of maize, sorghum, and other crops will also be produced.

Since irrigated agriculture is a new activity in the Bakel region, it will take some time to prepare land, train farmers, and bring production to full potential throughout the project area. Initial plans for the overall irrigation project estimated that the full 1900 hectares would not be cultivated before the project's fifth year; at best, double cropping would not be common before the eighth year. (U.S. AID, 1977, Annex D, pp. 1-3; Annex J, pp. 10-11.)

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*- On the Bakel system and solar thermal pumping in general, see D. FRENCH, 1978; THERMO ELECTRON CORP., 1977; U.S. AID, 1978a; J.D. WALTON et a'., 1978.

Where small diesel pumps are used, the rate at which an irrigation scheme expands makes little difference. As each new section of land is prepared for cultivation, a new pump is simply purchased to irrigate it. Problems arise, however, with the introduction of a solar pump which by itself can irrigate as much as 200 hectares. At least in Bakel, farmers are not going to abandon traditional lifestyles with the alacrity required to bring a section of this size rapidly into full production. Instead, the pump will have to remain partially idle as the government gradually prepares both land and people to fully use the water it can provide.

The pump's scale may affect its economics in other ways as well. On the remainder of the project, each diesel pump serves a limited number of farmers' groups, which together are responsible for its supervision and use. The solar installation, on the other hand, will serve up to ten times as many groups and will have to be supervised by highly-skilled technicians. Fragmentary evidence from nearby projects suggests that productive efficiency falls when agricultural decision-making is shifted from Senegalese farmers to government officials. Whether such effects prevail on land irrigated by the solar pump is an empirical question to be studied as the project proceeds. For purposes of analysis here, we assume that productivity will be the same on solar and diesel sections of the overall Bakel irrigation project.

The nature of solar thermal technology calls for pumps of a size which makes such problems almost inescapable. Solar units as small as the diesel systems to be used in Bakel would be prohibitively expensive. In fact, the manufacturers suggest that the Bakel solar pump itself is too small to take full advantage of economies of scale, implying that even larger units should be considered. (THERMO ELECTRON CORP., 1977, p. 11-5.) There is a dilemma here: on technical grounds, solar pumps should be as large as possible; on social and economic grounds, however, large pumps may be inconsistent with agricultural realities in developing countries.

C. Economic Analysis

The scale of the Bakel solar pump and the nature of the project in which it is to be placed hinder assessment of the system in private, commercial terms. It would be possible, of course, to imagine the "market" price at which the pump would deliver a given quantity of water. In principle, this price and other data could then be used to estimate financial returns to farmers relying on the pump for irrigated agriculture. In the Bakel case, however, land use is too complex to define a single, representative farming unit. Rather than inventing such a unit, we will simply analyze the solar pump project as a whole, from the economic perspective of national planners. (See Table 6.)

Table 6: Economic Analysis, 40-HP Solar Thermal Irrigation Pump Project, Bakel, Senegal

			Year			
	1	2	3	4	5	6-15
Benefits (in dollars)						
Production of rice, maize, sorghum [1]/*	---	86,700	188,900	252,000	252,000	252,000
- Costs (in dollars)						
Solar pump, installed [2]/	450,000	450,000	---	---	---	---
Land preparation, dikes, etc.	---	82,000	35,000	35,000	---	---
Administration (including buildings and vehicles)	20,000	60,000	14,000	10,000	7,600	7,600
Warehouses	---	6,000	6,000	6,000	---	---
Tools and equipment	---	2,000	1,000	1,000	---	---
Technical support, extension	15,000	22,000	18,000	11,000	7,000	4,500
Agricultural labor	---	4,500	10,000	13,400	13,400	13,400
Seed and fertilizer	---	15,000	37,000	50,000	50,000	50,000
= Net Economic Benefits	-485,000	-554,800	67,900	125,600	174,000	176,500
X Discount Factor (12%)	.893	.797	.712	.636	.567	3.206**
= Present Value, Economic Benefits	-433,100	-442,200	48,300	80,000	98,700	565,900

(3/ brackets Administration, Warehouses, Tools and equipment, Technical support, extension)

(4/ brackets Agricultural labor, Seed and fertilizer)

NET PRESENT VALUE = - $82,400; INTERNAL RATE OF RETURN = 10%[5]/

*- See "Notes to Tables 6-11", following Section VI.

**- 3.206 is the sum of the separate discount factors for Years 6 through 15. Multiplying annual benefits ($176,500) times 3.206 therefore gives the sum of the present benefits for all these years ($565,900).

The data used in this analysis are largely adapted from estimates developed for the original Bakel irrigation project. (U.S. AID, 1977.) Since the solar pump will irrigate 200 hectares, or 10.55% of the project area, costs in Table 6 are generally 10.55% of those for the overall project. (For details, see the "Notes to Tables 6-11" following Section VI.) Cultivation is assumed to spread steadily, with two crops grown annually on the full 200 hectares beginning in Year 4. Benefits per hectare will be the same as for the project as a whole.

Several favorable assumptions have been built into this analysis. Cost of the pumping system, for example, is recorded at the "multiple-unit" price of $900,000, rather than the actual cost of $1.25 million. The system is expected to run for 15 years with no breakdowns or repairs beyond routine preventive maintenance. It is assumed that 100 hectares will be cultivated during the first crop season, even though farmers on nearby sections of land irrigated by two diesel pumps were able to cultivate only 23 hectares in their first year. And several cost items included in the original Bakel project, notably a field trial station and surveillance of irrigation-related health problems, have been eliminated as not clearly essential to a solar pumping activity.

Nonetheless, assuming a 12% national discount rate, the solar pump project has a net present value of -$82,400,* corresponding to an internal rate of return of only 10%. Such returns are disturbingly low, especially given the high value of crops being produced. Net of seed and fertilizer costs, food production in Bakel is worth $.11 per cubic meter of water used, far above average values for irrigation projects worldwide. (D. SMITH and S. Allison, 1978, p. 16.) Since any appropriate pump should be quite profitable under these conditions, we have every reason to be dubious about the potential of the Bakel system.

This impression is confirmed through examination of the Bakel project as originally conceived. Including significant cost items not reflected in Table 6, but using diesel pumps exclusively, the project was expected to have an internal rate of return of 26%.

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*- Net present value would rise to about $23,500 if the project could be accelerated sufficiently to begin double cropping on all 200 hectares in Year 2. This would not be enough in itself to make the pump worthwhile, but it does indicate a certain degree of sensitivity to the speed with which land can be prepared and farmers convinced to use it.

D. Conclusions

Even given very favorable assumptions, costs of the Bakel solar pump threaten to be greater than the system's benefits. Since the value of irrigated agriculture in Bakel is unusually high, prospects for the pump would be even worse under most other plausible circumstances.

Given economies of scale, larger systems might cost appreciably less per unit of water pumped. On the other hand, larger pumps irrigate larger areas, possibly accentuating problems raised by the Bakel system itself: years may pass before the system can be used to full capacity; the need for elaborate government supervision and control may be inconsistent with initiative by basic farming units; at worst, farmers may end up serving as laborers on what are essentially state farms, with significant decreases in productivity. On balance, in other words, there is little reason a priori to assume that larger pumps would be economically more attractive than smaller ones.

Nor is there reason to believe that solar pumps of any size will become attractive simply as a result of future increases in the cost of diesel fuel. The Bakel pump has a negative net present value in its own terms, regardless of the cost of competing systems. The pump's manufacturers do estimate that diesel irrigation might be nearly as expensive as solar irrigation if the overall cost of pumping by diesel increased 10% annually over the next 15 years, exclusive of inflation. (THERMO ELECTRON CORP., 1977, Section 11.) Under such extreme conditions, it is possible that neither irrigation system would be worth its cost.

Eventually, technological breakthroughs might reduce the capital cost of solar pumps to a level where projects using these systems in developing countries would have respectable rates of return. In the Bakel case, for example, to reduce the pump's cost by 40% (to $540,000) would give the project a net present value of $221,800. The internal rate of return for solar pumping in Bakel would still not be as high as that expected using diesel units, but the chance that solar pumps might ultimately be appropriate for uses elsewhere would be considerably enhanced. Given advances as dramatic as this, comparative benefit-cost analyses of both diesel and solar pumps could again be carried out to determine which (if either) was appropriate for specific applications.

IV. FAMILY-SCALE INDIAN BIOGAS PLANT

A. The System

Although biogas systems theoretically can process most organic wastes, the raw material most commonly used is cow dung. Water is added to the dung in a mixing chamber, with the mixture then transferred to a closed fermentation tank. Over a period of weeks, the organic materials ferment in this anaerobic (airless) environment, producing methane, carbon dioxide, and traces of such other gases as hydrogen sulfide. These gases accumulate under a collector which "floats" on them at the top of the fermentation tank. An outlet valve in the collector allows gases to be withdrawn as needed. When the fermentation process is complete, the tank contains a slurry in which remain most of the original nitrogen and other plant nutrients.

Most of our knowledge of biogas systems is drawn from experience over the last quarter-century in India, although China recently has also begun to deploy family biogas plants in large numbers. The initial version of the basic Indian design was introduced by the Khadi & Village Industries Commission (KVIC) in 1954, and some 36,000 such plants now exist. (S. SUBRAMANIAN, 1978, p. 97.) Biogas units have also been built in the Republic of Korea, Taiwan, Thailand, and other countries.

B. The Project

The biogas "project" studied below is a composite, family-scale system whose details are drawn from a large number of sources.* The initial cost of the plant, installed, is 3,000 rupees (Rs), or about $375. To feed the unit, 175 pounds of cow dung and an equal amount of water are collected daily, mixed together, fed into the fermentation tank, and periodically stirred. Additional work is involved in removing an average of 315 pounds of slurry from the tank each day. Maintenance of the system costs about Rs 100 per year.

The system produces three cubic meters, or about 105 cubic feet, of biogas per day. Twenty cubic feet will be used for home lighting, with the remaining 85 cubic feet burned for cooking and heating. This volume of gas is sufficient to meet the daily needs of an Indian family of five to six people.

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*- E.g., A. BARNETT, 1978; R. BHATIA, 1977; KVIC, undated; R. LOEHR, 1978; NATIONAL ACADEMY OF SCIENCES, 1977; C. PRASAD, et al., 1974; L. PYLE, 1978; M. SATHIANATHAN, 1975; S. SUBRAMANIAN, 1978.

Our system will inevitably be owned by a relatively wealthy rural family. The initial cost, even assuming government subsidies, would be well beyond the means of anybody genuinely poor. In addition, to run the plant requires use of the dung from a minimum of three to four cows. Since fewer than 5% of Indian cattle-owners have this many animals, problems in ensuring command of the necessary supply of dung could be quite severe for all but the wealthiest families. (C. PRASAD, et al., p. 1360.)

C. Financial Analysis

In estimating costs and benefits of the biogas system (see Table 7), we assume that a family considering the system's purchase now uses soft coal for cooking, kerosene for lighting, and cow dung for fertilizer. Results of the analysis would be roughly the same if we assumed that dung was currently used as both cooking fuel and fertilizer.

Financial benefits of the gas therefore consist of the value of kerosene and coal which no longer need be purchased once gas is used for lighting and cooking. Benefits of the slurry consist of its fertilizer value, calculated in relation to the value of dung applied directly to the soil. The basis for assigning numbers to these benefits is outlined in the "Notes to Tables 6-11" following Section VI.

As noted above, labor requirements of the system are substantial. Even assuming that the dung itself can simply be gathered in the time formerly spent collecting other fuels, new labor is needed to gather water, to feed and maintain the system, and to unload and distribute the slurry. One authority estimates that manual labor for a plant of the size being considered here amounts to four hours per day, implying annual labor costs of Rs 912. (Cited in R. BHATIA, 1977, p. 1508.) In Table 7, we assume a much lower net labor requirement of two hours per day. Since much of this will be provided by family members, we arbitrarily value the labor at one-half the wage for unskilled agricultural workers, resulting in annual labor costs of Rs 180.

An even more critical assumption is that only routine maintenance will be required, with no breakdowns, shutdowns, or major problems over a project lifetime of 12 years. This may be giving the system the benefit of a very considerable doubt, since one study in India found that 71% of plant owners experienced technical problems, with a large number of units closed as a result. (Cited in A. BARNETT, 1978, p. 72.)

Table 7: Financial Analysis of 3 M^3/Day Biogas Plant, India

			Year			
	1	2	3	4	5	6-12
Benefits (in rupees)						
Gas for cooking and lighting [1]	380	380	380	380	380	380
Slurry for fertilizer [2]	340	340	340	340	340	340
− **Costs (in rupees)**						
Plant, installed [3]	3,000	---	---	---	---	---
Dung [4]	300	300	300	300	300	300
Collecting dung / Hauling water / Operating plant / Distributing slurry [5],[6] *	180	180	180	180	180	180
Maintenance	100	100	100	100	100	100
= **Net Financial Benefits**	-2,860	140	140	140	140	140
X Discount Factor (15%) [7]	.870	.756	.658	.572	.497	2.069
= **Present Value, Financial Benefits**	-2,488	106	92	80	70	290

NET PRESENT VALUE =-Rs. 1850; negative internal rate of return

*- net of labor otherwise spent collecting fuel

Even given these optimistic assumptions, the biogas plant has a negative internal rate of return and a net present value (at a 15% discount rate) of -Rs 1850. Although such a system apparently has no financial appeal, thousands have been installed. Further analysis is required to determine how this might have happened.

One possible explanation would be to assume that buyers pay no attention to such non-monetary costs as those for family labor. This assumption is rather implausible, since at least part of the labor required will be diverted from other productive tasks, especially during peak agricultural periods. Moreover, just as we suppose that people will impute some financial benefit to being relieved from arduous work, we can reasonably suppose they will impute a cost to added hours of labor.

Nonetheless, we will assume for the moment that the potential buyer views labor required to run the system as having no cost. We can equally assume that construction labor included in the plant's original price will be provided free by family members. For the sake of consistency, we suppose also that no cost is attributed to dung collected from family animals. (This implies, however, that the slurry produced by the system is of no financial benefit, since its value is calculated in relation to the cost of dung replaced.) In this extreme form, such assumptions are clearly unreasonable, but they do serve to increase the system's net present value by Rs 1525. Unfortunately for our need to understand why such systems would be bought, however, net present value even in this case is only -Rs 325.

Perhaps more to the point is to note that heavy subsidy programs existed until recently to support purchase of biogas units in India.* Until 1973, for example, KVIC provided biogas grants of $35-42 per system, along with interest-free loans of up to $285, repayable over a period of as much as 10 years. (S. SUBRAMANIAN, 1978, p. 100.) In Table 8, our family biogas plant is evaluated on the assumption that such a subsidy will be provided. If reasonable costs are again attributed to labor, however, the system still has a negative internal rate of return and a net present value of -Rs 615.

In practice, given the circumstances under which biogas loans were made, many buyers may have been led to assume that loan repayments would be optional. In addition, such noneconomic forces as prestige or a desire for clean cooking

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*- The importance of subsidies can be seen in the fact that when Korea terminated its extensive biogas subsidy program, construction of new units essentially stopped. (A. BARNETT, 1978, p. 83.)

Table 8: Financial Analysis of 3 M^3/Day Biogas Plant, India (As Subsidized) 1/

	Year					
	1	2	3	4	5-11	12
Benefits (in rupees)						
Gas for cooking and lighting	380	380	380	380	380	380
Slurry for fertilizer	340	340	340	340	340	340
Grant	300	---	---	---	---	---
Loan	2,250	---	---	---	---	---
- Costs (in rupees)						
Plant, installed	3,000	---	---	---	---	---
Dung	300	300	300	300	300	300
Labor	180	180	180	180	180	180
Maintenance	100	100	100	100	100	180
Loan repayment	---	225	225	225	225	---
= Net Financial Benefits	-310	-85	-85	-85	-85	140
x Discount Factor (15%)	.870	.756	.658	.572	2.378	.187
= Present Value, Financial Benefits	-270	-64	-56	-49	-202	26

NET PRESENT VALUE = -Rs. 615; negative internal rate of return

fuel may have enhanced the appeal of biogas systems. Most likely, a combination of these factors served to make an otherwise unattractive investment seem worthwhile to buyers. Whatever the explanation in specific cases, it took heavy government subsidies to bring things to this point, raising the question of whether the system was sufficiently worthwhile from the national point of view to justify such support.

D. Economic Analysis

Table 9 examines the family biogas plant according to national economic measures. Shadow pricing results in a slight increase in the value of gas, a decrease in the cost of the plant, and use of a lower discount rate. Since we had already valued labor at half its market cost, the same procedure we have followed in establishing shadow wages, no adjustment is necessary in total labor costs. Provision is made for government extension services in support of the plant.

Given these assumptions, the biogas system has a negative internal rate of return and a net present value of -Rs 1952. From the national point of view, in other words, the system looks even worse than it did from the financial perspective of the individual buyer. In economic terms, family biogas units are distinguished chiefly by the efficiency with which they digest money.

E. Conclusions

On the evidence, family-scale biogas plants of the sort now used in India seem a most dubious investment from the point of view of everyone except their manufacturers. It has been suggested that costs of such plants could be lowered and economic returns raised by reducing the amounts of steel and cement involved in their construction. Although this may ultimately prove possible, it should be noted that a number of unsuccessful attempts have already been made to use bamboo, wood, plastics and other materials in place of cement and steel. (S. SUBRAMANIAN, 1978, pp. 97, 98, 101, 113.) Moreover, cement and steel account for only 40% of the installed cost of the system we have been examining. Even if use of these materials were reduced to zero, the system would still have a negative net present value in both financial and economic terms.

Also proposed have been community-based plants, on the assumption that these might make economic sense where family systems do not. Presumably, community members would deliver dung to a central collection point, with gas then piped to their homes. Slurry would be composted and made available for fertilizer. Unfortunately for the sake of detailed analysis, however, no such systems have been tried.

Table 9: Economic Analysis of 3 M^3/Day Biogas Plant, India

	Year 1	2	3	4	5	6-12
Benefits (in rupees)						
Gas for cooking and lighting [1]	395	395	395	395	395	395
Slurry for fertilizer	340	340	340	340	340	340
- Costs (in rupees)						
Plant, installed [2]	2,865	---	---	---	---	---
Dung	300	300	300	300	300	300
Labor [3]	180	180	180	180	180	180
Maintenance	100	100	100	100	100	100
Extension services [4]	250	25	25	25	25	25
= Net Economic Benefits	-2,960	130	130	130	130	130
X Discount Factor (12%) [5]	.893	.797	.712	.636	.567	2.590
= Present Value, Economic Benefits	-2,643	104	93	83	74	337

NET PRESENT VALUE = -Rs 1952; negative internal rate of return

Whatever its advantages in terms of economies of digester scale, a community biogas plant implies heavy additional costs as well. Management could be extremely expensive, with a requirement for complex mechanisms to buy dung and to sell gas and slurry. Skilled technicians would be needed to run the system. Dozens of tons of water would have to be acquired for the plant every day. Costly distribution networks and special pumps to move gas through them would be needed to meet home cooking needs. Although only careful benefit-cost analysis of specific proposals could suggest their actual merit, there is clearly no assurance at this point that community plants would be more desirable than family ones.

The implications for other developing areas are hardly more encouraging. The basic economics of a family-scale plant would be much the same anywhere. In many countries, however, people gather their own wood rather than buying commercial fuels such as coal for cooking. In such cases, using biogas will yield no cash benefits to offset the large amounts of money required to pay for the unit itself. Whatever the project's returns on paper, such an investment will look extremely uninviting in terms of actual cash flows.

Where biogas is to replace firewood, national economic analysis can be adjusted to reflect reduced pressure on fragile woodlands. One way to do this would be to estimate the area which a family would denude of trees for firewood in the absence of the biogas system. Expenditures which would otherwise have been needed in order to reforest this space could then be included as an economic benefit of the system. If such an approach is necessary to salvage the system, however, it will almost certainly be more economical simply to plant the trees and to forego the biogas, which in itself is a losing proposition.

This conclusion is reinforced by the fact that where woodlands are particularly scarce, water is likely to be scarce as well. Since biogas plants demand great quantities of water, they may therefore be even less feasible than usual precisely where firewood is dwindling most rapidly. In many parts of Africa, where firewood problems are especially acute, studies show that women may spend four hours or more on each journey to collect water. (M. CARR, 1978, p. 34.) Biogas plants, which consume 175 pounds per family of additional water every day, are obviously not what such areas need.

Ironically, biogas makes best sense in areas which already are relatively developed. China's family biogas units, for example, are connected to home toilets, an amenity generally unavailable in rural areas of the Third World.* When allowance is made for benefits of waste disposal and treatment of human pathogens, the Chinese units have appreciable economic advantages over those using cow dung alone. Biogas is also worth

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*- On biogas in China, see M. McGARRY and J. Stainforth (eds.), 1978.

much more in place of electricity or natural gas than it
is in place of firewood or dung. Although this could be
of interest to people using expensive commercial energy,
few of the poor in developing countries now cook on electric
stoves.

In sum, it is difficult to imagine any circumstances
where family biogas plants would make sense for the poor
in most developing areas. Community systems remain a
mystery, but one which experience with smaller units suggests
we should approach with the most extreme caution.

V.   LAKE CHAD SOLAR CELL PUMP

A.   The System

Althou.h scientifically complex, solar (or "photovoltaic") cells are conceptually quite simple: when the sun falls on a solar cell, electricity is produced. By joining large numbers of these cells together, significant amounts of power can be generated wherever the sun shines.*

For pumping water, solar cells are connected through a voltage regulator to an electric pump. To ensure that water will be available on cloudy days or at night, provision is made either for battery storage of electricity (allowing the pump to be used anytime) or for a reservoir into which water can be pumped during sunny periods and held until needed.

B.   The Project

Both AID and the World Bank have investigated irrigated agriculture for the borders of Lake Chad. Specifically, water is supplied to "polders," fertile areas between the ancient sand dunes which extend like fingers from the shore into the lake. Ultimately, one wheat crop and one cotton crop could be grown on this land each year.

Although no specific provision has yet been made to include solar cell pumps in a Lake Chad polders project, enough data have been gathered to allow reasonable estimates of the feasibility of such pumps.** In the project evaluated below, a hypothetical 5.5 kw solar cell pump provides water to grow wheat and cotton on 12 hectares of irrigated polder.

C.   Financial Analysis

In Table 10, we have assumed that solar panels, ex-factory, cost $3 per peak watt, the price which might apply in 1983 if 100 such systems were purchased simultaneously. (The comparable present price is close to $10 per peak watt.) To find the cost of the solar system as installed at Lake Chad, we must add a voltage regulator, transportation of the solar array from the U.S. to Chad, and construction of a supporting structure. To produce electricity from solar cells at Lake Chad therefore costs $4.36 per peak watt of output, $1.36 of which would apply even if the solar panels were free.

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*- On solar cells, see K. BOSSONG, 1978; DEVELOPMENT SCIENCES, INC., 1977; R. GOFF and C. Currin, 1977; M. PRINCE, 1978; D. SMITH, 1977; C. WEISS and S. Pak, 1976.

** - See, e.g., META SYSTEMS, Inc., 1974; D. SMITH, 1977; WORLD BANK, 1975b.

Table 10: Financial Analysis, 5.5 KW Solar Cell Irrigation Pump, Chad

| | \
Year | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6-12 |
| **Benefits (in dollars)** | | | | | | |
| Wheat and cotton production[1]/ | 5,300 | 11,100 | 11,100 | 11,100 | 11,100 | 11,100 |
| **- Costs (in dollars)** | | | | | | |
| Solar panels, ex-factory ($3/p.w.) | 16,500 | --- | --- | --- | --- | --- |
| Voltage regulator | 4,000 | --- | --- | --- | --- | --- |
| Surface transport of solar array, U.S.-Chad | 1,500 | --- | --- | --- | --- | --- |
| Structure and installation [3]/ | 2,000 | --- | --- | --- | --- | --- |
| Battery [3]/ | 1,000 | --- | --- | --- | --- | --- |
| Pump and motor, delivered [4]/ | 5,500 | --- | --- | --- | --- | --- |
| Irrigation channels and land preparation[5]/ | 34,000 | --- | --- | --- | --- | --- |
| Tools and equipment[6]/ | 1,500 | --- | --- | --- | --- | --- |
| Maintenance[7]/ | 15 | 15 | 15 | 15 | 15 | 15 |
| Agricultural labor[8]/ | 1,025 | 2,050 | 2,050 | 2,050 | 2,050 | 2,050 |
| Seed, fertilizer, and other operating costs[9]/ | 760 | 3,020 | 3,020 | 3,020 | 3,020 | 3,020 |
| = Net Financial Benefits | -62,500 | 6,015 | 6,015 | 6,015 | 6,015 | 6,015 |
| X Discount Factor (50%)[10]/ | .667 | .444 | .296 | .198 | .132 | .249 |
| = Present Value, Financial Benefits | -41,688 | 2,671 | 1,780 | 1,191 | 794 | 1,498 |

2/

NET PRESENT VALUE = - $33,754; INTERNAL RATE OF RETURN = 1%

To these electricity costs must be added irrigation and agricultural expenses: pump and motor; storage battery; irrigation channels and land preparation; tools; maintenance; labor, seed and fertilizer. Benefits of this activity consist of the income earned by farmers for wheat and cotton produced. Here, we assume that one crop (wheat) will be produced in Year 1, two crops (one wheat and one cotton) in Years 2-12.

Assuming a discount factor of 50% (probably below the actual rate for farmers in the Lake Chad region), the project has a net present value of -$33,754 and an internal rate of return of 1%. Clearly, very considerable subsidies would be required to encourage farmers to use solar cell pumps for irrigation. It remains to be seen whether this activity is sufficiently worthwhile from the national point of view to warrant such subsidies.

D. Economic Analysis

In economic terms, benefits are considerably higher than by financial measures. (See Table 11.) This is because economic benefits are valued according to the import price for cotton and wheat in the Lake Chad area. Financial benefits, on the other hand, assumed that farmers would actually be paid a significantly lower price for their crops by the agencies responsible for agricultural marketing.

Other economic adjustments are relatively standard. Labor has been shadow-priced at one-half the wage used for financial calculations. A "typical" national discount rate of 12% has been used. Provision has been made for the costs to the government of necessary technical support and extension services.

As might be hoped, given the high value of crops produced, economic returns to solar cell irrigation on Lake Chad polders are considerable. Net present value of the activity is $38,793; the project's internal rate of return is 26%. Viewed strictly in its own terms, without reference to competing systems, the Chad solar cell pumping project would appear to be worthwhile.

E. Conclusions

Clearly, under favorable assumptions as to solar panel costs, the possibilities for growing high-value crops, and the ease of introducing unfamiliar agricultural patterns in a remote area of Africa, the solar cell pump will pay for itself in economic (if not financial) terms. At this point, it becomes worthwhile to compare the solar system with the diesel pumps actually planned for use in the Lake Chad polders project.

Table 11: Economic Analysis, 5.5 KW Solar Cell Irrigation Pump, Chad

	Year					
	1	2	3	4	5	6-12
Benefits (in dollars)						
Wheat and cotton production[1]/	5,500	23,410	23,410	23,410	23,410	23,410
- Costs (in dollars)						
Solar array, installed	24,000	---	---	---	---	---
Battery	1,000	---	---	---	---	---
Pump and motor, delivered	5,500	---	---	---	---	---
Irrigation channels and land preparation[2]/	27,200	---	---	---	---	---
Tools and equipment	1,500	---	---	---	---	---
Maintenance	15	15	15	15	15	15
Agricultural labor[3]/	515	1,025	1,025	1,025	1,025	1,025
Seed, fertilizer and other inputs	760	3,020	3,020	3,020	3,020	3,020
Technical support[4]/	5,000	3,000	3,000	3,000	3,000	---
Extension[5]/	475	315	315	315	315	315
= Net Economic Benefits	-60,465	16,035	16,035	16,035	16,035	19,035
X Discount Factor (12%)	.893	.797	.712	.636	.567	2.590
= Present Value, Economic Benefits	-53,995	12,780	11,417	10,198	9,092	49,301

NET PRESENT VALUE = $38,793; INTERNAL RATE OF RETURN = 26%

In his study of solar cell pumping at Lake Chad,
Douglas Smith (1977, p. 46) concludes that "photovoltaic
power for irrigation pumping is competitive with diesel
pumping at solar array costs of $1000 per peak kw at current
diesel fuel prices." Assuming that diesel prices have risen
by 4% annually over the ten-year period ending in 1984,
solar cell pumping would then be competitive at an array
cost of $1300 per peak kilowatt, or $1.30 per peak watt.

As noted above, however, solar array costs at Lake Chad
would be $1.36 per peak watt, installed, <u>even if the solar
cells themselves were free</u>. Since actual solar cell prices
in the 1980s will range from $.40 to $5.00 or more per peak
watt, ex-factory, the returns to solar pumping systems at
Lake Chad will be significantly less in the foreseeable
future than returns to diesel alternatives. This conclu-
sion, by the way, is consistent with economic analysis by
U.S. AID of a comparable irrigation scheme in Mali. (U.S.
AID, 1978, Appendix I.) In the Mali case, diesel pumps also
proved more cost-effective than pumps relying on solar panels,
even assuming a solar cell price of zero.

Solar pumps are likely to prove even less interesting
in other countries than the analysis here would suggest.
In Bangladesh, India, and Pakistan, for example, Smith
found that "photovoltaic power for irrigation pumping is
less competitive than in Chad because of fewer pumping hours
. . . less solar radiation, lower fuel costs, and higher
heads . . ." (1977, p. 47.)

Such conclusions might require qualification if diesel
power itself proved inappropriate for particular tasks. The
energy required to run an educational television set or
a fractional horsepower irrigation pump, for example, could be
well below the capacity of the smallest diesel units. Solar
cell units of very small size will be more readily available.*
Neither village television nor "micro-irrigation" using solar
cells would pay for itself financially, however; and the eco-
nomic value of these systems is problematic. In the aggregate,
the potential of solar cells for such small-scale applications
now appears quite limited.

In sum, there is no evidence that solar cells will have
widespread developmental uses over the next few years. As
far as can be determined, even reduction of solar cell prices
to near zero would not materially alter this conclusion.
Given very rapid increases in the cost of conventional energy
systems, however, solar cells might become appropriate for such
applications as high-value irrigation projects in the late 1980s.

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*- See, e.g., C. CURRIN and E. Warrick, 1977; D. SMITH and
   S. Allison, 1978.

It is worth stressing that solar cell electricity under
the most optimistic assumptions will be far more expensive
than the energy (human, animal, firewood) now applied to
most tasks by the world's poor. It is therefore not the poor
for whom these systems are primarily destined. Instead,
as solar cell systems become more competitive, they will
prove of interest first to investors who are already using
expensive commercial energy--that is, to the relatively
wealthy. Only much later would any substantial benefits
filter down to the mass of people whose energy needs
are now most desperate.

VI. CONCLUSIONS

From the discussion above, it is possible to draw useful conclusions about:

- analytical issues which arise in pursuing benefit-cost analyses of renewable energy devices, and

- the developmental promise of devices such as solar cells, solar pumps, and biogas plants.

A. The Pursuit of Benefit-Cost Analysis

Concluding points involve the need for benefit-cost analysis before energy systems are field-tested, the need for local information, and the use of benefit-cost data in decision-making.

1. Preliminary Benefit-Cost Analysis. Obviously, the first quick look at a new energy device can be quite misleading. Not so obviously, early judgments will almost inevitably overstate the advantages of a new system. In practice, important project elements tend to be ignored until at least preliminary benefit-cost analysis is undertaken. As these "hidden" items emerge, returns to the project are likely to fall. For example:

- Economic benefits may prove unexpectedly low in the absence of alternative employment for people released from work by a new device.

- Expenses may increase when provision is made for the actual cost of such apparently "free" resources as the dung or water used in biogas plants.

- Effective discount rates in poor areas may be far above those to which we are accustomed, greatly diminishing a project's present value.

- Local attitudes toward risk and uncertainty may prove more conservative than our own, dooming systems which we might ourselves have viewed as acceptably risky.

- Using shadow prices for imported goods can significantly increase their cost.

- The need for extension services in support of new energy systems may increase their cost to society well beyond the level which financial analysis alone would suggest.

Such forces will not be equally prominent in all projects. Moreover, they may be partially offset as we uncover a project's hidden benefits. Still, it is customary for many more costs than benefits initially to escape even the unbiased eye. Coupled with the natural impulse for proponents of new systems to view the world through rosy lenses, this suggests that energy devices will systematically be overrated in the early stages of their review.

The obvious conclusion here is that energy systems should be subjected to preliminary benefit-cost analysis even before projects are created to test them in the field. There are costs in following this approach, of course--but much, much greater costs in avoiding it.

2. Local Information. Many renewable energy projects are designed to free people from such tasks as grinding grain or hauling wood and water. The benefits of these projects consist largely of the alternative work people can do in time freed from traditional jobs. The same device may therefore be enormously profitable in one area (where new work is readily available) and financially disastrous in another (where few productive opportunities exist). Only when we have solid information on local conditions can we predict which will be the case.

Local values of other variables can also influence the desirability of a new energy system. If benefit-cost analyses are adequately to account for these forces, we will need specific local information on at least the following items:

- value of a system's output (if measurable in market prices);

- alternative employment opportunities (to measure benefits if the system chiefly releases labor from former tasks);

- costs of site preparation and installation of the system;

- direct operating costs;

- degree of local unemployment (to find shadow wages);

- existing uses of raw materials (to find their shadow price);

- extension costs of introducing the system;

- market interest rates for local borrowing (to estimate investors' discount rates);

- characteristic local investments (to suggest willingness to take financial risks).

A given system need <u>not</u> be in place before these data can be collected. Instead, existing knowledge about a device's technical characteristics can be combined with local economic information to arrive at estimates of its costs and benefits. As has been argued above, at least preliminary work along these lines should be carried out <u>before</u> decisions are made to test new systems in the field.

To broaden our store of useful data, it would also be help-ful to add relevant economic questions to local energy surveys of the sort being planned by the World Bank in Colombia and by the Peace Corps in a number of other countries. Simply by asking about local interest rates, employment patterns, and investments, for example, surveyors at this level could increase manyfold our ability to judge the attractiveness of energy systems.

If preliminary analysis suggests that field-testing of a system would be appropriate, additional economic data-gather-ing should be made an integral part of this process. Unfor-tunately, field tests tend to be organized almost exclusively around technical questions. At best, direct operating costs may be recorded, although even these are often neglected. Given the importance of economic analysis in drawing conclu-sions about a system's desirability, we should ensure that <u>all</u> field tests measure <u>all</u> economic variables listed at the beginning of this section.

3. <u>The Use of Benefit-Cost Data</u>. In principle, benefit-cost analysis should provide clear guidance in deciding whether or not to support an energy technology. Economic analysis shows whether the technology is advantageous to society. If economic results are positive, financial analysis indicates whether subsidies are required to interest investors in the activity. Given such information, national planners allocate the funds required to promote the new system.

In fact, reality is somewhat more complex than this. On a number of counts, benefit-cost information may not tell the whole story about the prospects for a new energy system:

- In terms of financial analysis, we have taken for granted that a farmer (for example) will evaluate a proposed irrigation pump by comparing expected benefits with expected costs, giving greater weight to immediate returns than to distant ones. We do not expect the farmer's analysis to be highly mathematical, but we assume that in essence it will parallel the approach to financial analysis outlined in Section I. The actual basis for investment decisions by the very poor in developing countries is only imperfectly understood, however; and our financial estimates will therefore only approxi-mate reality until they are tested in the field.

- For the national planner as well as the private investor, benefit-cost data are only one measure of an energy system. Other criteria might include such factors as village self-reliance, national prestige, energy independence, public health, or improved technical skills.* Benefit-cost analysis can show the price of pursuing these objectives by using a system which might not otherwise be worthwhile; decision-makers are then left to judge whether this price is reasonable.

- From the standpoint of the economic analyst, it is tempting to conclude that a system with high returns is "really" attractive, even if substantial subsidies are required to make it appealing to local investors. This is only true, however, if there is a reasonable expectation that subsidies will actually be forthcoming. Since governments have more claims on resources than resources, subsidies for a given system might be highly improbable. In such a case, there would be little justification for pursuing an energy proposal, regardless of its theoretical appeal on economic grounds.

Obviously, the economist is not king (or queen) when it comes to final decisions on energy technologies. Nonetheless, benefit-cost analysis is a minimum condition for thinking clearly about new systems. At the least, such analysis will help eliminate inexcusable systems and suggest improvements in useful ones. If non-economic forces encourage governments to choose "unprofitable" energy projects or to reject "profitable" ones, benefit-cost data will show the economic and financial consequences of such action. Although not conclusive in themselves, these contributions are fundamental to sound decision-making.

B.   Renewable Energy Systems

The energy devices studied in Sections III-V are broadly representative of those to which greatest attention is now being given by the development community. In terms of technological possibilities, however, such devices are only a small part of a spectrum which ranges from solar cells and thermal pumps to village woodlots and improved mud stoves. The following section suggests that defective economics may have contributed to narrowing the range of inquiry in this way. A final section considers the promise of specific systems.

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*- A wide range of non-economic criteria are discussed in A. BARNETT, 1978.

1. The Implications of Discount Rates. Discount rates
used by the poor to evaluate their investments may be consider-
ably higher than rates prevailing in urban capital markets.
We have already noted that using the appropriate, higher rate
will make a considerable difference in calculating the finan-
cial returns to energy systems. Choice of the correct rate
is important in another way as well: depending on the rate
used, we might come to very different conclusions about which
of various competing systems is worthy of serious consideration.

This latter effect is most evident when comparing relatively
capital-intensive technologies (of the sort examined in Sections
III-V) with more labor-intensive approaches (at the mud stove
and woodlot end of the spectrum). Capital-intensive systems
typically pile heavy investment charges into the first year,
with compensation in the form of large net benefits in later
years. At high discount rates, where the present value of
future benefits is dramatically reduced, it may be difficult
to recover initial costs. Labor-intensive projects, which
seldom involve as much early red ink, are less vulnerable to
the impact of discount rates on future benefits.

To illustrate the point, consider the effect of alternative
discount rates on two hypothetical water pumps, one relying
on solar cells and one pedal-driven. Each system is able to
do ₺50 worth of pumping annually for five years. The solar
cell pump, however, involves much higher capital costs (₺150
vs. ₺45) and much lower recurrent costs (₺5 vs. ₺35). In Table
12, net present values are calculated for these systems at
discount rates of 20% and 30%.

At a discount rate of 20%, the solar cell pump has a higher
net present value (₺9.6 vs. ₺7.3). At 30%, however, the pedal-
driven system is superior (NPV of ₺1.9 vs. -₺5.7 for the solar
cell pump). As this illustration suggests, higher interest
rates generally favor labor-intensive systems; lower interest
rates give the advantage to capital-intensive devices.

These tendencies are also important as we switch to economic
analysis, where extremely low "shadow" discount rates are used.
Fortunately for the prospects of devices like our pedal-driven
pump, the impact of shadow discount rates may be more than
offset by low shadow wages, which clearly benefit labor-inten-
sive systems. Nonetheless, the principle holds that low inter-
est rates in themselves are the friend more of sophisticated
technologies than of simple ones.

In practice, analysts have tended seriously to underestimate
the level of discount rates prevailing in poor areas. One
result has been to focus attention almost exclusively on rela-
tively complex energy systems. The danger here is that poor
economics will lead to support for devices which in reality

Table 12: Present Values of Hypothetical Pumping Systems

Solar Cell System

	Year				
	1	2	3	4	5
Benefits (water pumping)	50	50	50	50	50
- Costs					
Solar cell pump	150	0	0	0	0
Labor	5	5	5	5	5
= Net Benefits	-105	45	45	45	45
Present Value (30%)	-80.7	26.6	20.5	15.8	12.1
Present Value (20%)	-87.5	31.2	26.1	21.7	18.1

NET PRESENT VALUE AT 30% =-Ŀ5.7; AT 20% = Ŀ9.6.

Pedal-Driven System

	Year				
	1	2	3	4	5
Benefits (water pumping)	50	50	50	50	50
- Costs					
Pedal-driven pump	45	0	0	0	0
Labor	35	35	35	35	35
= Net Benefits	-30	15	15	15	15
Present Value (30%)	-23.1	8.9	6.8	5.3	4.0
Present Value (20%)	-25.0	10.4	8.7	7.2	6.0

NET PRESENT VALUE AT 30% = Ŀ1.9; AT 20% = Ŀ7.3.

are too unprofitable for investors and too capital-intensive
for people in search of work. The proper choice of discount
rates would suggest that a broader range of energy systems, in-
cluding quite simple ones, deserves serious attention.

2. <u>The Promise of Energy Devices</u>. In Sections III-V, we examined the relationship between benefits and costs of three renewable energy systems, as applied to rural needs in developing countries. In each case, gross benefits were well above average levels which could be expected to prevail in such projects. Further, costs were systematically adjusted downward to take account of economies now assumed to be within reach over the next few years.

Nonetheless, results were far from encouraging:

- Although near the low end of the current cost range for comparable systems, the Bakel solar pump proved quite marginal by benefit-cost measures. Diesel pumps evaluated within the same project promised far higher returns.

- Family-scale biogas systems in India proved extremely unprofitable in both financial and economic terms, with no reason to suppose that conditions would be more favorable in other countries. Lack of experience prohibits even tentative judgments about community biogas plants, which in practice could prove either more or less attractive than family units.

- A solar cell pump in Chad promised substantial economic returns for irrigating high-value crops, although heavy subsidies would be required to make the system financially appealing to farmers. Diesel pumps to do the same work, however, seem more attractive under all plausible assumptions as to costs of diesel and solar cell pumping over the next decade. Solar cell power is likely to be even less cost-effective in other countries and might not pay for itself at all for less high-value applications than pumping of irrigation water.

These conclusions would not necessarily be the same for renewable energy systems to be used by the rich. As we have seen, the "benefits" of new systems are often measurable in terms of the energy they replace. For an American using a modern stove, the benefits of cooking with biogas would be equal to the cost of electricity which would then not have to be used. For an African cooking on an open fire, biogas would be worth the cost of twigs her children would no longer have to collect. Financial appraisal of the same biogas system would yield very different results for these two applications.

For reasons such as these, most renewable energy devices now tend to be attractive primarily to people already using costly commercial power. Just as is happening in the United States, for example, some Third World city-dwellers are discovering that solar energy may be cheaper than electricity for heating water. Similarly, in looking at solar cell pumps, we noted

that these will first become competitive with relatively
expensive forms of energy. Such systems will be of greatest
use to the wealthy; there is little reason to suppose they
will be of comparable interest to the poor.

Rather than concentrating on devices of the sort con-
sidered above, organizations concerned with the poor might seek
to meet basic energy needs through simpler systems: village
woodlots, improved wood stoves, hand or pedal pumps and grinders,
hydraulic ram pumps, and so on.* Emphasis would be on systems
whose benefits were likely to be commensurate with their costs,
and whose costs were likely to be within reach of the poor.
Given this approach, ways might be found to make energy widely
available to people most in need of it. If economic analysis
is any guide, there is little reason to expect this result from
such devices as solar pumps, solar cells, or biogas plants.

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* - See, e.g., M. CARR, 1978; WORLD BANK, 1976.

NOTES TO TABLES 6-11

Table 6

1.   Benefits per hectare are as estimated for the Bakel Small
Irrigated Perimeters project.   (See U.S. Aid, 1977, Annex J,
pp. 10-11.)   In Table 1, we assume that one crop will be
grown on 100 hectares in Year 2; two crops will be grown on
150 hectares in Year 3; two crops annually will be grown on
all 200 hectares in Years 4-15.   At full production, 1.9 mil-
lion cubic meters of water will be pumped annually (op. cit.,
p. 18), yielding benefits (net of seed and fertilizer) of
$.106 per cubic meter.

2.   Actual price of the Bakel solar pump is $1.25 million.
However, the manufacturers estimate that costs would fall
to $900,000 if ten systems were made simultaneously.   (Thermo
Electron Corp., 1977, p. 11-5.)   Table 1 uses this "multiple
system" price.   In rough accord with actual provisions of
the Bakel project, we have assumed that payment is made in
equal installments upon signing of the contract (Year 1) and
final acceptance of the system (Year 2).

3.   Assumes that costs on the 200 hectares irrigated by the
solar pump are 10.55% of costs on the 1896 hectares of the
overall Bakel project (200/1896 = .1055).   Bakel data are
provided in U.S. AID, 1977, pp. 89-93.   The actual costs of
a project of only 200 hectares might well be higher.

4.   Figures drawn from U.S. AID, 1977, Annex J, pp. 10-11.
Daily labor costs are assumed to be 75 CFA (about $.31)
per worker.   (U.S. AID, 1977, p. 64.)

5.   Assuming that only diesel pumps were used, the Bakel project
as a whole was estimated to have an internal rate of return
of 26%.   (U.S. AID, 1977, p. 63.)

Table 7

1.   Of 105 cubic feet of gas produced per day, we assume
that 20 cubic feet will be used in place of kerosene for
home lighting, with the remaining 85 cubic feet used in place
of coal for cooking.   Market value of the kerosene replaced
is equal to its "shadow" cost of Rs 162/year (R. Bhatia, 1977,
p. 1505), less the foreign exchange premium included in the
shadow price (op. cit., p. 1517, note 6), or a total of Rs
131/year.   Market value of the coal replaced is equal to

its "shadow" cost of Rs 217/year (op.cit., p. 1505), plus labor costs not included in the shadow price (op. cit., p. 1517, note 9), or a total of Rs 247/year. Total financial benefits are therefore Rs 378/year.

2. Little solid information exists on the relative fertilizer value of dung and slurry, although it is known that up to 18% of nitrogen in the original dung may be transformed into ammonia in the biogas conversion process and then lost through volatilization. (National Academy of Sciences, 1977, p. 49.) To give the system the benefit of the doubt, the value of the slurry has been calculated here as 113% of the value of dung, in line with one finding that slurry may be 13% "more effective" as a fertilizer. (S. Subramanian, 1978, p. 120.) Estimates showing a greater increase in fertilizer value appear to measure available nitrogen after the slurry is composted with other farm and household wastes, a method which incorrectly attributes to the biogas process the value of added wastes not involved in that process. (See, for example, Khadi & Village Industries Commission, undated, pp. 2-12; M. Sathianathan, 1975, pp. 83, 164.)

3. Cost of the plant is as provided in National Academy of Sciences, 1977, p. 120, and is consistent with data in S. Subramanian (1978, p. 97) and elsewhere. C. Prasad et al. (1974, p. 1355) note that steel and cement account for only 40% of the plant's original cost, with labor, fittings and appliances accounting for the rest.

4. Valued per National Academy of Sciences, 1977, p. 121. Approximately 175 pounds of dung are involved, assuming that 1 pound of dung yields 0.6 cubic feet of gas. (Op. cit., p. 119; C. Prasad et al., 1974, p. 1364; L. Pyle, 1978, pp. 40, 52.)

5. Assumes that two hours of work are required per day, beyond the labor which would be employed collecting fuel in the absence of the biogas plant: collecting dung, 0 net hours per day (i.e., same as formerly spent collecting fuel); hauling 175 pounds of water (L. Pyle, 1978, p. 54), 1/2 hour per day; mixing inputs and operating plant, 3/4 hour per day (R. Bhatia, 1977, p. 1508); distributing 315 pounds of slurry (350 pounds inputs time 0.9, per National Academy of Sciences, 1977, p. 83), 3/4 hour per day. Approximately 90 working days of extra labor are therefore required per year. We assume here that investors value labor (much of it provided by family members) at one-half the unskilled agricultural wage of Rs 4/day (A. Barnett, 1978, p. 88). Labor costs are therefore Rs 180 per year.

6. Estimate, including painting of gas holder, as provided by National Academy of Sciences, 1977, p. 121. This figure is consistent with Korean data cited in NAS, 1977, p. 20 (Table 1-5, note "a").

7. According to the World Bank (1975a, p. 79), interest rates on commercial loans to Indian farmers average 15%. This figure is consistent with available information on biogas loans, where interest rates ranging from 12% (S. Subramanian, 1978, p. 100) to 17% (National Academy of Sciences, 1977, p. 22) have been reported. Since unsubsidized interest rates on agricultural lending approximate farmers' discount rates, we assume here a discount rate of 15%.

Table 8

1. Assumes a government grant of Rs 300 and an interest-free loan of Rs 2,250, repayable in equal installments during Years 2-11. This corresponds to the highest level of support provided by India's Khadi & Village Industries Commission before 1973, when biogas subsidies began to be reduced. (S. Subramanian, 1978, p. 100.)

Table 9

1. Gas to be used for lighting reflects a shadow price of Rs 162 for the kerosene being replaced, in line with estimates by R. Bhatia, 1977, p. 1505. Bhatia's shadow price for coal to be replaced by gas for cooking (Rs 217) assumes that labor involved in mining the coal (market cost of Rs 30) has no social cost. (Op. cit., p. 1517, note 9.) Since we assume here that shadow wages are half the market wage rather than zero, we add Rs 15 to Bhatia's estimate, giving a value for cooking gas of Rs 232. As used for both cooking and lighting, total economic benefits of the gas are therefore Rs 394. (See also Note 1, Table 7.)

2. Of total market costs (Rs 3000), we assume that 40% (Rs 1200) take the form of steel and cement. To reflect the value placed on foreign exchange, a premium of 20% must be added to these items, giving them a "shadow price" of Rs 1440. Another 25% of market costs consist of unskilled labor used to build the system; given a shadow wage of half the market wage, economic costs for such labor are Rs 375. The remaining 35% (Rs 1050) of the plant's initial cost consists of fittings and skilled labor, for which market and shadow prices are assumed to be the same. Total cost of the plant in economic terms is therefore Rs 2,865. (Adapted from R. Bhatia, 1977, p. 1508.)

3. Ninety days of labor per year at one-half the market wage of Rs 4/day. (See Note 5, Table 7, where it is assumed that investors also value their family labor at half its market price.)

4. In Year 1, assumes two weeks of extension services by a village-level worker (VLW) making Rs 6,000/year, plus Rs 10 in attention from a biogas technician. This covers such items as: training of the VLW in biogas technologies (pro-rated); time spent in demonstrations of biogas technologies and in initial discussions with interested families (pro-rated); assistance in arranging credit and purchase of hardware; assistance in construction, start-up, and testing of the system; follow-up and repairs. In Years 2-12, provi-sion is made for about one day of extension assistance per year.

5. A discount rate of 12% is used in line with J. Price Gittinger's observation that as "a rule of thumb" this "seems to be a popular choice" in national economic analysis. (1972, p. 90.)

Table 10

1. Figures assume one crop (wheat) in Year 1, two crops (one cotton, one wheat) in Years 2-12. Payment to farmers for goods produced amounts to $463 per hectare for wheat and $491 per hectare for cotton. $29 has been deducted per hec-tare to account for traditional goods no longer produced as a result of the project. (World Bank, 1975b, Annex 3, Table 2.) The project covers 12 hectares. (D. Smith, 1977, p. 23; the area has been adjusted from 12.6 to 12 hectares to re-flect the actual size of standard irrigation units in the polders project.)

2. Manufacturer's estimates, assuming that panels for 100 such pumps were purchased simultaneously. For an order of 550 peak kw, solar panels are expected to cost about $3 per watt in 1983.

3. Per D. Smith, 1977, p. 25.

4. The pump and motor cost about $5,000, ex-factory in France (Manufacturer's estimate.) An additional $500 has been includ₁ for transportation to Chad.

5. One percent of the cost of irrigation works (less pump-ing stations) for a 1200-hectare Lake Chad polders scheme. (World Bank, 1975b, Annex 7, Table 2.) These costs are high due to transportation problems and lack of local exper-ience with construction of irrigation works.

6. World Bank, 1975b, Annex 3, Table 3.

7. Per D. Smith, 1977, p. 27.

8. World Bank, 1975b, pp. vi, 27.

9. World Bank, 1975b, Annex 3, Table 3.

10. Interest rates on unsubsidized agricultural credit are assumed to approximate farmer's discount rates. In five African countries, the World Bank (1975a, p. 79) found that agricultural interest rates averaged 117%. We arbitrarily assume here that the discount rate will be significantly lower, although above the Bank's estimated global average of 32% for unsubsidized agricultural credit. (Op. cit., p. 29.)

Table 11

1. "Economic" returns are based on the import price of these goods rather than the price actually paid to farmers by marketing agencies. The economic value of output per hectare is $480 for wheat and $1500 for cotton. From total output, $260 has been deducted in Year 1 and $350 in subsequent years to reflect lost income from traditional activities no longer pursued as a result of the project. (World Bank, 1975b, Annex 9, Table 2, as adjusted for economic rather than financial values.)

2. Assumes that 40% of total costs are for unskilled labor, which is assigned a shadow wage half its market wage. Economic costs of irrigation works are therefore 20% less than financial costs.

3. The shadow wage is assumed to be one-half the wage used for financial analysis.

4. Adapted from World Bank, 1975b, Annex 7, Table 1. Expatriate salaries have been excluded.

5. Estimate by Meta Systems, 1974, p. 126. We assume that first-year costs will be 50% greater than those incurred in subsequent years.

ANNOTATED BIBLIOGRAPHY

1. ADAMS, Dale W. 1977. <u>Policy Issues in Rural Finance and</u>
    <u>Development</u>. Conference on Rural Finance Research (San
    Diego, July 28 - August 1, 1977), Paper No. 1. June 15.

    Although small farmers may have to pay 40-50% to borrow
    from local moneylenders, the actual cost of credit
    from central institutions can be almost as high once
    allowance is made for such "transaction costs" as
    bribes, rejected loan applications, travel expenses,
    and time spent on paperwork and negotiations. Trans-
    action costs are less significant for larger borrowers,
    who therefore are happy to absorb available credit at
    nominal interest rates which tend to be artificially
    low (in real terms, often negative). Coupled with the
    fact that lending institutions prefer in any case to
    deal with larger borrowers, the result is a system
    which transfers substantial income to rich farmers while
    offering little to the poor.

2. BALDWIN, George B. 1972. "A Layman's Guide to Little/
    Mirrlees," In <u>Finance and Development</u>. March.
    (Reprinted in <u>W. JONES</u>, ed., 1975.)

    Characterizes the project evaluation book by Little and
    Mirrlees as a "textbook of appraisal theory," rather
    than an operating manual for project designers. This
    is most evident in the book's insistence on calculating
    world prices for all inputs and outputs, a process
    which "involves a lot of trouble for a doubtful advan-
    tage." Little and Mirrlees also propose to value
    savings generated by development projects more highly
    than the additional consumption they allow, an approach
    which is easier to appreciate than to apply. On other
    important counts, the book tends to observe accepted
    project appraisal methods.

3. BARNETT, Andrew. 1978. "Biogas Technology: A Social and
    Economic Assessment." In A. BARNETT, et al., 1978.

    Biogas projects should be considered in the overall con-
    text of rural development needs, of which energy prob-
    lems are only a part. Assuming that villagers do express
    needs that biogas systems might meet, evaluation must
    take place in terms of specific local realities, both
    economic and social. Considers major issues in bene-
    fit-cost analysis, while noting that decision-makers
    should also allow for the impact of biogas systems
    on income distribution, employment, the environment,
    and local self-reliance. Reviews five of the best
    case studies of biogas systems, suggesting that inad-
    equacies of measurement and approach so far make it

impossible to draw firm conclusions about the value
of these systems. Among issues in urgent need of
further research are ways to lower capital costs and
to establish community-scale plants. Only if progress
is made in these areas will biogas technology be of
value to more than the relative handful of wealthy
farmers who are now its beneficiaries.

4. BARNETT, Andrew, et al. 1978. _Biogas Technology in the_
   Third World: A Multidisciplinary Review. Ottawa:
   International Development Research Centre.

   Three long essays on the theory and practice of biogas
   production, including major technical, economic, and
   social issues. To date, almost all biogas systems
   have been heavily subsidized and sold to relatively
   wealthy farmers. While implying that biogas might
   ultimately serve the poor as well, all three contrib-
   utors stress that major problems must be solved and
   much better data acquired before firm conclusions on
   this point would be justified. Under these conditions,
   there is "a real danger that attempts are being made
   at wide-scale introduction of these techniques in the
   rural areas of the Third World before it is known
   whether they are in any sense appropriate to the prob-
   lems of rural peoples." For summaries of the three
   essays, see entries under A. BARNETT (1978), L. PYLE
   (1978), and S.K. SUBRAMANIAN (1978).

5. BERRY, Sara S. 1977. _Risk and the Poor Farmer._ Report
   to U.S. AID. August.

   A critical review of the literature on poor farmers'
   behavior with respect to risk. Concludes that "unpro-
   gressive" behavior is more a result of limited finan-
   cial capacities to bear risk than of unwillingness to
   do so. Efforts to reduce the risk of agricultural pro-
   duction are therefore no substitute for redistribution
   of income.

6. BHATIA, Ramesh. 1977. "Economic Appraisal of Bio-Gas Units
   in India: Framework for Social Benefit Cost Analysis."
   In _Economic and Political Weekly_ (special number). August.

   The best available report on the economics of biogas
   plants. Based on an extensive review of the literature,
   the article discusses valuation of capital costs, opera-
   ting costs (dung, labor), and major benefits (gas,
   slurry), as well as secondary effects (e.g., improved
   health). Using shadow prices, calculates the Net
   Present Value (NPV) of systems able to produce 2 or 3
   cubic meters of gas per day. Under almost all sets
   of assumptions, these systems are socially unprofitable.

> If biogas is used mainly for cooking, as opposed to
> lighting, the systems would have negative NPVs even
> if future research could reduce capital costs by 30%.
> Use of biogas in place of diesel fuel for irrigation
> pumps is also uneconomic. Since "present estimates
> . . . do not indicate that investment in biogas units
> is economic from the viewpoint of society," concludes
> that attention might better be given to irrigation
> projects, creation of rural industries, and subsidized
> coke for home cooking.

7. BOSSONG, Ken. 1978. Solar Cells. Report Series No. 27.
    Washington, D.C.: Citizen's Energy Project. August.

    Summarizes current information on photovoltaics, includ-
    ing research, publications, and uses. Notes that the
    price of solar cells has fallen from $300 to about $11
    per peak watt over the past four years. Prices may
    drop to $.50 by 1986 and to $.10 or less by 1990. In
    the United States, solar cells are already being used
    in remote areas to power such devices as radio repeaters,
    refrigerators, pumps, and navigation lights. Since
    solar electricity becomes competitive with power from
    nuclear and fossil fuels at a price of $.50 per peak
    watt, work is also underway on industrial and residen-
    tial applications.

8. BROWN, Maxwell L. 1977. The Use of Budgets in Farm
    Income and Agricultural Project Analyses. Washington,
    D.C.: World Bank, Economic Development Institute.
    August.

    Approaches analysis of agricultural projects through
    budget data from individual farms. These data are used
    to find profits from a farm's separate enterprises,
    along with net income for the farm as a whole. Indicates
    adjustments necessary in using this information to find
    financial and economic rates of return for projects
    affecting one or more farms.

9. BROWN, Norman L. (ed.). 1978. Renewable Energy Resources
    and Rural Applications in the Developing World. AAAS
    Selected Symposium 6. Boulder, Colorado: Westview Press.

    See listings under R.C. LOEHR (1978) and M.B. PRINCE
    (1978).

10. BROWN, Norman L. and James W. Howe. 1978. "Solar Energy
    for Village Development." In Science. February 10.

    Discusses estimates made in Tanzania during a 1977 work-
    ship jointly sponsored by the National Academy of
    Sciences and Tanzania's National Scientific Research

Council. Relative to the cost of electricity from
central grids or diesel generators, a number of solar
technologies are now (or will soon be) competitive:
solar cells, small hydroelectric generators, wind-
mills, biogas systems, solar refrigerators.

11. CARR, Marilyn. 1976. Economically Appropriate Tech-
    nologies for Developing Countries: An Annotated
    Bibliography. London: Intermediate Technology Publi-
    cations Ltd.

    Includes a number of listings covering such energy
    topics as solar grain drying, gobar gas, charcoal,
    windmills, biomass, and solar distillation. An intro-
    ductory essay emphasizes the difficulty of general-
    izing from such selections, since specific technology
    issues and appropriate responses vary greatly depend-
    ing on place, state of development, etc.

12. CARR, Marilyn. 1978. Appropriate Technology for African
    Women. Addis Ababa: U.N. Economic Commission for Africa.

    Estimates that one-sixth of all energy expended by
    rural African women is used for collecting water. This
    burden might be eased through adoption of rainwater
    catchment systems, hydraulic ram pumps, or hand pumps.
    To reduce labor required to haul firewood, more effi-
    cient wood stoves might be introduced. Grinding of
    staple crops could be done more easily with hand-,
    pedal-, or animal-powered grinding mills. Simple
    tools could also make better use of human or animal
    energy for land preparation, food processing, animal
    husbandry and other functions. Describes current pro-
    grams to test such systems in Africa.

13. CURRIN, C.G. and E.L. Warrick. 1977. Preliminary Study
    of Solar Electric Generator Fabrication by Developing
    Nations. A Dow Corning Solar Energy Report. Midland,
    Michigan: Dow Corning. June 30.

    Proposes to reduce the cost of photovoltaic power by
    assembling solar cell arrays in developing countries.
    A factory to produce 1,000 systems per year for power-
    ing television sets would require initial capital of
    $150,000. By using local workers, annual labor costs
    are reduced to $35,000 for 17 employees. Raw material
    imports amount to $200,000 annually, about half in the
    form of silicon wafers made by companies like Dow
    Corning. Systems cost $380 installed, resulting in
    power charges of $.80/kwh to run a television set for
    5.5 hours per day, 250 days per year. These costs
    are significantly below those of systems assembled
    by workers in developed countries. Such analysis
    justifies "a major tentative conclusion: local fabri-
    cation in developing countries of solar-electric gener-
    ators is practical and preferred."

14. DAINES, Samuel R. 1977. An Overview of Economic and Data Analysis Techniques for Project Design and Evaluation. Course Manual for Data and Economic Analysis Weeks, AID Development Studies Program. Washington, D.C.: AID. August.

A grab bag of techniques for collecting, analyzing and presenting information about AID's primary development concerns: income, nutrition, health, production, population, and education. Included are such topics as sampling procedures, household income accounts, land and capital profitability ratios, histograms, input-output methods, and benefit-cost analysis. Since the information to which these techniques are applied is often sketchy, the author argues for greater care in basic data-gathering as part of project design and evaluation.

15. DEVELOPMENT ALTERNATIVES, Inc. 1976. Small Farmer Risk-Taking. Report to U.S. AID. Washington, D.C.: Development Alternatives, Inc. June 1.

Notes that no consensus exists on the meaning or significance of "risk" and "uncertainty" as confronted by small farmers. For the sake of discussion, defines uncertainty as "a perception of there being more than one possible outcome from a particular act." Risk is involved if any outcome would fall below some minimum acceptable level. In general, poor farmers seem to be more "risk-averse" than rich ones, although little more can be said due to the inadequacy of research on the subject. Risk-aversion is probably minimized where new techniques are closely related to old ones, farmers are expected to contribute labor rather than money to the project, cooperation among farmers is encouraged, and dependence on outsiders is avoided.

16. DEVELOPMENT SCIENCE, Inc. 1977. Photovoltaics and the Less Developed Countries. Report to U.S. AID. September 28.

In isolated areas with abundant sunshine, photovoltaic power might be used for refrigeration and ice-making, pumping of drinking or irrigation water, humidifying of stored peanuts, lighting, food processing, or protecting grain from rats (using tiny electric fences strung a few millimeters off the ground around storage areas). Photovoltaic systems may be cheaper than diesel power for such jobs, although actual cost comparisons are highly sensitive to specific local conditions.

17. FRENCH, David. 1977. _Economic and Social Analysis of Renewable Energy Projects: The State of the Art._ Report to U.S. AID. November 22.

   Notes that sound energy programming for rural areas requires information and analytical capabilities of four major sorts: technical, financial, economic, and social/institutional. To date, however, serious attention has been given only to technical aspects of rural energy problems. In economic and financial terms, this means that work so far is simply inadequate to indicate whether renewable energy sytems are feasible in developing countries.

18. FRENCH, David. 1978. _Social Monitoring and Evaluation of the Bakel Solar Pump._ Report to U.S. AID. March 17.

   Suggests that the size and complexity of the Bakel solar pump could have adverse effects on the pump's profitability. For example, several years may pass before the full 200 hectares which the pump can irrigate is actually cultivated. In addition, the need for centralized supervision of the pump by highly-trained technicians could shift important agricultural decisions from farmers to government, leading to a fall in productivity. Proposes a system for monitoring and evaluating such effects.

19. GITTINGER, J. Price. 1972. _Economic Analysis of Agricultural Projects._ Baltimore: The Johns Hopkins University Press.

   Covers major ways of measuring agricultural projects: benefit-cost ratios, net present worth (or value), and internal rates of return. Drawing on cases from developing countries, shows how these techniques are used to find both financial ("private") and economic ("social") returns to projects. Discusses practical problems of identifying and measuring costs and benefits.

20. GITTINGER, J. Price (ed.). 1973. _Compounding and Discounting Tables for Project Evaluation._ Baltimore: Johns Hopkins University Press.

   Includes discount factors for Years 1-50 of a project at discount rates of 1-50%.

21. GOFF, R.M. and C.G. Currin. 1977. Preliminary Economic
    Study of Solar-Electric and Diesel-Electric Generators.
    A Dow Corning Solar Energy Report. Midland, Michigan:
    Dow Corning. July 20.

    A manufacturer of solar cells weighs the merits of
    solar cells as opposed to diesel generators for remote
    communities in developing nations. Concludes that solar
    cells will produce electricity in significant amounts
    for about $.35/kwh, vs. $.50/kwh for diesel generators.
    Built into these "base line" numbers are assumptions
    such as these: the interest rate is 5%; the price of
    diesel fuel starts at $.40 per liter and rises 7% per
    year; the solar cell system will last 20 years with
    zero maintenance; solar cells cost $6 per peak watt,
    including shipping and installation; no energy storage
    or power conditioning is required for the solar system;
    average daily power generated by the solar system will
    be equivalent to 4.1 hours of output at peak capacity.
    According to the report's own sensitivity analyses,
    simply to use more realistic assumptions about initial
    fuel costs ($.30 per liter) and interest rates (10%)
    would make the diesel system more attractive.

22. HANSEN, John R. 1975. "A Guide to the UNIDO Guidelines:
    Social Benefit/Cost Analysis in Developing Countries."
    In W. JONES (ed.), 1975.

    A rather complex condensation of the UNIDO "Guidelines,"
    intended for operational use by technicians in developing
    countries. Deals with commercial and economic profita-
    bility of projects, adjustments to reflect the distri-
    bution of benefits between investment and consumption
    and between different income groups, and ways of allow-
    ing for the social value of goods produced.

23. JONES, William I. (ed.). 1975. Readings on Project
    Analysis Methods. Washington, D.C.: World Bank,
    Economic Development Institute.

    A number of long selections on benefit-cost analysis,
    including discussions of the Little-Mirrlees and UNIDO
    approaches. (See entries under G. BALDWIN, 1972; J.
    HANSEN, 1975.)

24. KHADI & VILLAGE INDUSTRIES COMMISSION. Undated. Gobar
    Gas: Why and How. Bombay: KVIC.

    Intended for potential buyers of biogas plants, this
    pamphlet briefly outlines technical and economic
    aspects of biogas production. Emphasizes assistance
    available from KVIC for people installing such systems.

With respect to use of slurry, recommends that this
be composted in alternate layers with farm sweepings
or household wastes: Economic analysis attributes
no cost to these wastes but includes their fertilizer
value as part of "annual income" from the biogas plant.

25. LAL, Deepak. 1974. Methods of Project Analysis: A
Review. World Bank Staff Occasional Papers No. 16.
Baltimore: The Johns Hopkins University Press.

A rather technical comparison of alternative project
selection procedures, notably the UNIDO (1972) and
LITTLE-Mirrlees (1974) approaches. Concentrates on
distortions in foreign trade and domestic factor mar-
kets (capital and labor), problems of income distri-
bution and employment, and debt service issues. Con-
cludes that the competing methods of selection lead
ultimately to similar conclusions, although sometimes
by dissimilar analytical routes.

26. LITTLE, I.M.D. and J.A. Mirrlees. 1974. Project
Appraisal and Planning for Developing Countries. New
York: Basic Books.

A basic work on benefit-cost analysis of development
projects. For commentary on the Little-Mirrlees
approach, see entries under G. BALDWIN, 1972; D. LAL,
1974; H. SCHWARTZ, 1977.

27. LOEHR, Raymond C. 1978. "Methane from Human, Animal
and Agricultural Wastes." In N.L. BROWN (ed.), 1978.

Methane plants make gas and slurry from waste materials.
Conversion efficiency depends on many factors, includ-
ing the nature of the wastes, possible contamination
by dirt or chemicals, ratio of carbon to nitrogen, temp-
erature, retention times, and the specific technology
used. In industrialized countries, where people now use
fossil fuels for energy, studies indicate that biogas
production for the most part is not competitive. In
developing countries, where people are too poor to use
fossil fuels, biogas may show more promise. Final
conclusions about specific local applications will de-
pend on careful evaluation of their technical, economic,
and social feasibility.

28. MAKHIJANI, Arjun. 1976. "Solar Energy and Rural Develop-
ment for the Third World." Bulletin of the Atomic
Scientists. June.

Argues for community biogas plants as a way of meeting
energy needs, increasing agricultural production, and
providing employment.

29. MARGLIN, Stephen. 1977. "The Essentials of the UNIDO
     Approach to Benefit-Cost Analysis." In H. SCHWARTZ
     and R. Berney (eds.), 1977.

         Notes three major differences between the UNIDO
         Guidelines (1972) and other approaches to cost-bene-
         fit analysis. First, the Guidelines explicitly
         take into account such "social" objectives as improved
         income distribution. Second, analysis is based on
         the assumption that the countries involved will continue
         to exist in a state of economic disequilibrium. Third,
         important weights (e.g., for income distribution) are
         determined inductively after allowing decision-makers
         to choose between a number of project alternatives
         (reflecting, e.g., tradeoffs between current output
         and redistribution of benefits).

30. MCGARRY, Michael G. and Jill Stainforth (eds.). 1978.
     Compost, Fertilizer and Biogas Production from Human
     and Farm Wastes in the People's Republic of China.
     Ottawa: International Development Research Centre.

         Translations of largely technical articles from Chinese
         sources. Concentrates on new ways to treat wastes
         now deposited in home toilets and pigpens. Special
         emphasis is placed on the extent to which the biogas
         conversion process reduces pathogens in human excre-
         ment. No economic data are provided on either costs
         or benefits of the systems described.

31. META SYSTEMS, Inc. 1974. Analysis of "Revelle" Polders
     Development Scheme and Design for a Long Range Lake
     Chad Basin Study. Working Draft Report to U.S. AID.
     Cambridge, Mass.: Meta Systems, Inc. October 8.

         Considers possibilities for irrigated agriculture in
         polders on the borders of Lake Chad. Reviews alterna-
         tive means of lifting water, including human, animal,
         wind, gasoline, diesel, and electric power. Concludes
         that diesel pumps are likely to be most economical.

32. NATIONAL ACADEMY OF SCIENCES. 1977. Methane Generation
     From Human, Animal, and Agricultural Wastes. Report of
     an Ad Hoc Panel of the Advisory Committee on Technology
     Innovation. Washington, D.C.: National Academy of
     Sciences.

         Converting crop residues and animal wastes to biogas
         reduces health dangers associated with the wastes,
         provides fuel for such purposes as cooking and
         running small engines, and leaves a sludge which makes
         excellent fertilizer. Biogas systems are sensitive
         to a number of factors: temperature, diet of animals
         whose wastes are being used, mix and particle size of

raw materials, exposure of raw wastes or sludge to
rain, susceptibility of digestion equipment to corro-
sion, etc. Design of a digester and expectations
as to its output must therefore be tailored to re-
sources, climate and building materials in the speci-
fic location where it is to be built. As a result,
considerable technical assistance may be required
to implement a large-scale biogas program. Although
biogas systems have been tried extensively in India,
Taiwan, China and Korea, little is known about their
actual technical performance, the fertilizer value
of sludges produced, or operating costs. Existing eco-
nomic analyses are far too inadequate for conclusions
to be drawn as to the financial or economic desirability
of biogas systems. Concludes that "more information
is required before this approach can be recommended
for large-scale adoption ... "

33. OHIO STATE UNIVERSITY, Department of Agricultural Eco-
nomics and Rural Sociology. 1972, 1976, 1977. Agri-
cultural Credit and Rural Savings (3 vols.). AID Biblio-
graphy Series: Agriculture Nos. 7-9. Washington, D.C.:
U.S. AID.

Three volumes of annotated bibliography on agricultural
credit and rural savings. The 1976 edition lists
contents of the 20 volumes of material produced by AID's
1973 "Spring Review of Small Farmer Credit."

34. PAK, Simon J. and Charles R.H. Taylor. 1976. Critical
Factors in Economic Evaluation of Small Decentralized
Energy Projects. Science and Technology Report No. 25.
Washington, D.C.: World Bank. November.

Notes that projects to develop alternative energy sources
should be evaluated in terms of total costs and bene-
fits to the economy (not simply the investor), includ-
ing calculation of secondary effects and appropriate
shadow prices. Care should be taken not to overestimate
benefits (e.g., by using data for plant capacity rather
than actual output) or to underestimate costs (e.g.,
through excessive optimism as to the operating life of
equipment). Where forms of energy are not already traded
locally, their value may have to be set according to
that of energy sources being replaced, or in terms of
the project's net impact on the production of other goods.
If this process of collecting and evaluating data were
standardized, a useful body of international knowledge
could ultimately be developed on the economics of alter-
native energy.

35. PRASAD, C.R.; K. Krishna Prasad; and A.K.N. Reddy. 1974. "Bio-Gas Plants: Prospects, Problems and Tasks." In Economic and Political Weekly IX (32-34).

> In an imaginary village of 500 people and 250 cows, use of available dung and night soil would yield enough biogas to meet present energy needs for pumping, lighting, cooking, and small-scale industrial uses. This biogas might be competitive with energy from rural electrification, which itself is apparently too expensive to be used for the purposes listed. From this, "it was concluded that bio-gas plants are the answer to the energy problem." Nonetheless, unresolved questions do remain with respect to ownership, distribution and storage systems, water requirements, etc.; and "drastic" cost reductions are required before the full potential of biogas can be realized. Lists 31 research and development issues requiring immediate attention.

36. PRINCE, Morton B. 1978. "Photovoltaic Technology." In N.L. BROWN (ed.), 1978.

> Describes efforts of the U.S. Department of Energy to help reduce solar cell costs. By 1986, standard solar arrays could cost as little as $.50 per peak watt; including collectors and cells, concentrating systems could cost $.25 per peak watt. Potential applications for developing countries include power for televisions sets, water pumps, refrigerators, cereal grinders, and tourist facilities.

37. PYLE, Leo. 1978. "Anaerobic Digestion: The Technical Options." In A. BARNETT, et al., 1978.

> To place biogas production in context, considers alternative ways of supplying energy or fertilizer needs, using local wastes, addressing public health problems, and using anaerobic digesters. With respect to actual production of biogas in developing countries, stresses that useful information is extremely scanty. In part, this is because results vary greatly with digester design and with such local variables as temperature, raw materials, and supervisory abilities. In addition, much of the available data on these questions is "perhaps hopeful rather than realistic." Few conclusions can therefore be drawn as to the actual efficiency of biogas systems, the fertilizer value of slurries, reasons for "the relatively high reported failure rate of simple digesters," or other questions involved in deciding whether digesters are worthwhile. In terms of priorities for futher work, emphasizes reductions in capital costs and development of community-scale systems.

38. ROUMASSET, James A. 1977. Risk and Uncertainty in Agricultural Development. A/D/C Seminar Report No. 15. New York City: The Agricultural Development Council. October.

   Summarizes results of a conference held in 1976 on risk and uncertainty. On these points, "there is a considerable gap between the frontier of knowledge and the tools that practitioners in the field are applying." The gap may prevail for some time, since the report reflects a "frontier of knowledge" where people as yet are unable to define risk, to agree on how this should be measured, or to create models that explain attitudes or behavior of actual farmers.

39. SATHIANATHAN, M.A. 1975. Biogas Achievements and Challenges. New Delhi: Association of Voluntary Agencies for Rural Development.

   A detailed study of biogas production. In a chapter on uses of slurry, suggests that this is most effective as a starter for composting other waste materials. This approach is reflected in subsequent economic analysis, where "income" from biogas production includes the full value of composted matter, less than half of which is slurry from the biogas plant itself.

40. SCHAEFER-KEHNERT, W. 1978a. The Phasing of Inflow and Outflow in Farm Cash Flow Projections. Economic Development Institute Course Note CN-8 (revised). Washington, D.C.: World Bank. June.

   In evaluating a new project, traditional cash flow projections lump together in the "Year 1" column the initial investment and end-of-year totals for revenues and costs. Since both investments and expenses for agricultural activities may come early and benefits late in a given year, the result is to overstate the project's rate of return and understate the farmer's need for working capital. To correct for such distortions, the author proposes time adjustments to reflect more accurately the characteristic phasing of outflows and inflows for different types of farms.

41. SCHAEFER-KEHNERT, W. 1978b. How to Start an Internal Rate of Return Calculation. Economic Development Institute Course Note CN-30 (revised). Washington, D.C.: World Bank. August.

   Provides tables for estimating a project's internal rate of return, given information about annual benefits over the project's life.

42. SCHAEFER-KEHNERT, W. 1978c. Measuring Small Farmers'
Development Incentives. Economic Development Institute
Course Note CN-58 (draft). Washington, D.C.: World
Bank. August.

Argues that internal rates of return are an inadequate
measure of investment incentives for small farmers,
since such farmers are more concerned with increased
net income than with maximizing the return to their
capital. Proposes that the measure of a project's
allure be its incremental net benefits as a percent
of net benefits flowing to the farmer in the project's
absence.

43. SCHWARTZ, Hugh. 1977. "An Overview." In H. SCHWARTZ,
and R. Berney (eds.), 1977.

Summarizes proceedings of a symposium on project
evaluation sponsored by the Inter-American Development
Bank in 1973. Among basic issues was the extent to
which such "social" criteria as income distribution
can and should be included in project analysis. Also
examined in detail were social rates of discount;
shadow prices of investment, labor, and foreign exchange;
and distinctions between the UNIDO (1972) and LITTLE-
Mirrlees (1974) approaches to project evaluation.
Participants agreed that although cost-benefit tech-
niques are weak in accounting for externalities and
ranking dissimilar activites, they in general have
great value in eliminating bad development projects
and improving the design of good ones.

44. SCHWARTZ, Hugh and Richard Berney (eds.). 1977. Social
and Economic Dimensions of Project Evaluation. Washing-
ton, D.C.: Inter-American Development Bank.

Material from the IDB's 1973 symposium on project eval-
uation, including background papers, edited transcripts
of presentations and discussion, and a summary of the
proceedings. (See S. MARGLIN, 1977; H. SCHWARTZ, 1977.)

45. SIRKEN, Irving A. 1975. Risk Analysis and Uncertainty.
Document 01-975-0090. Washington, D.C.: World Bank,
Economic Development Institute. January.

A project's internal rate of return (IRR) may vary
greatly with changes in important variables. If
assigning the least favorable values to all such varia-
bles still yields an IRR greater than the opportunity
cost of capital, the project is unacceptable. Other-
wise, it may be useful to calculate several IRRs, in
each case using a pessimistic value for one variable
and the most likely values for the rest. Coupled with

estimates as to the probabilities of each outcome, this information will help planners decide whether the project is too risky to undertake. More sophisticated results are possible using a computer and the "Monte Carlo" method, by which the probabilities assigned to behavior of key variables are combined to show the probability of achieving alternative rates of return.

46. SMITH, Douglas V. 1977. <u>Photovoltaic Power in Less Developed Countries</u>. Report to ERDA. Lexington, Mass.: MIT, Lincoln Laboratory. March 24.

Compares photovoltaic and diesel systems, on the assumption that: the diesel systems themselves are worth their cost; credit is available at 10%; there are no costs for transporting equipment from the U.S. or installing it in the country of use; solar arrays have a lifetime of 20 years with no management or maintenance costs. Under these conditions, solar cells would be competitive with diesel for low-lift irrigation pumps at Lake Chad, assuming year-round agriculture and a solar array cost of $1 per peak watt. Photovoltaic irrigation is less competitive in Bangladesh, India and Pakistan, where sunlight is less and fuel costs lower. For solar cells to be competitive for providing drinking water, rice hulling and lighting in a typical Indian village, diesel fuel would have to cost $.30 per liter (67% above current levels) and solar cells $.50 per peak watt (94% below current costs). There is no reason to assume that photovoltaics will offer more benefit to the poor than any other expensive system for providing power (diesel, grid). This is especially obvious in the case of water pumping, for which "Photovoltaics are as capital-intensive a . . . technology as can be imagined."

47. SMITH, Douglas V. and Steven V. Allison. 1978. <u>Micro Irrigation with Photovoltaics</u>. MIT Energy Laboratory Report MIT-EL-78-006. Cambridge, Mass.: MIT, Energy Laboratory. April.

Considers feasibility of photovoltaic irrigation systems for farms of 1-2 hectares. Estimates that such systems would be financially attractive under the following conditions: the soil is exceptionally fertile; abundant water is available; the peak watt cost of a power pack used for rice irrigation is less than $8.60 where surface water is used and less than $2.75 in the case of ground water; there are no costs for such items as irrigation canals, maintenance, management or extension; life of the system is 15 years; and complete financing is available to farmers at 10% interest.

Since solar cells can now be bought for $8 per
peak watt, the report concludes that "Solar pumping
of irrigation water is thus economical today."
Recommends a program to place 10 million photovoltaic
pumping units in developing countries over the next
20 years, at a capital cost of $3.5 billion.

48. SQUIRE, Lyn and Herman G. van der Tak. 1975. Economic
Analysis of Projects. A World Bank Research Publication.
Baltimore: The Johns Hopkins University Press.

Discusses benefit-cost analysis of development projects,
with emphasis on ways of calculating shadow prices.
Considers methods for taking explicit account of a
project's impact on the distribution of income between
investment and consumption and between rich and poor.

49. SUBRAMANIAN, S.K. 1978. "Biogas Systems in Asia: A
Survey." In A. BARNETT et al., 1978.

Reviews biogas experience in a dozen Asian countries,
with special attention to events in India, South Korea,
the Philippines, Thailand, Indonesia, and Japan. In
general, biogas plants have been installed by the rela-
tively rich, aided by substantial government subsidies.
No community biogas systems appear to be in use, although
only systems of this sort are likely to serve the poor.
While the greatest benefits of biogas derive from the
use of slurry as fertilizer, reliable data do not exist
on the actual value of slurry for this purpose. Other
benefits include provision of cooking gas, better health,
increased self-reliance, expanded technical skills,
reduced deforestation, and cleaner living conditions.
At least outside of China, researchers have had little
success in attempts to reduce the cost of biogas instal-
lations through use of PVC or local construction materials.

50. THERMO ELECTRON CORPORATION. 1977. Proposal to the Govern-
ment of Senegal: A Solar Thermal Water Pumping System
for Bakel, Senegal. Waltham, Mass.: Thermo Electron
Corp. December 15.

A primarily technical review of a 30 kw (40 hp) solar
pumping system for use in an irrigated agriculture scheme
along the Senegal River. A brief economic analysis
compares solar and diesel systems, concluding that
the solar pump is competitive given a low discount rate,
rapid price increases for diesel fuel, and a long,
trouble-free lifetime for the solar pump.

51. U.N. INDUSTRIAL DEVELOPMENT ORGANIZATION. 1972.
     Guidelines for Project Evaluation. New York: United
     Nations.

       A basic work on benefit-cost analysis of development
       projects. For commentary on the UNIDO approach, see
       entries under J. HANSEN, 1975; D. LAL, 1974; S. MARGLIN,
       1977; H. SCHWARTZ, 1977.

52. U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT. 1977.
     Small Irrigated Perimeters Project Paper (Bakel, Senegal),
     2 Vols. Washington, D.C.: U.S. AID. May 15.

       Provides details of the irrigation project into which
       the Bakel solar pump is to be introduced. (See entries
       under D. FRENCH, 1978; THERMO ELECTRON CORP., 1977;
       U.S. AID, 1978a.)

53. U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT. 1978a. Bakel
     (Senegal) Solar Pump (project paper amendment). Washing-
     ton, D.C.: U.S. AID. March 10.

       Provides funds to cover U.S. costs of a 30 kw solar
       pump ($625,000), as well as evaluation of the system's
       social and economic impact ($75,000). In addition,
       the Government of France will pay $625,000 for those
       components of the pump to be made by SOFRETES. Upon
       installation, the pump will be able to provide irriga-
       tion water for 200 hectares of land along the Senegal
       River.

54. U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT. 1978b. Mali
     Renewable Energy Project Paper (Appendix I: "Economic
     Analysis"). Washington, D.C.: U.S. AID. June.

       Compares photovoltaic and diesel pumps to irrigate about
       3.4 hectares of vegetable gardens in Mopti, Mali. Ini-
       tial cost of a 1300-watt solar pump is $48,150 ($23,400
       for solar panels and hardware, delivered to Bamako;
       $7,100 for pump, control system, and motor; $500 to
       transport equipment from Bamako to Mopti; $6,500 for a well;
       $9,800 for storage tank and fence; $850 for supervision of
       the pump's installation). Initial cost of a diesel
       system is $10,000 ($3,500 for a diesel pump, delivered to
       Mopti; $6,500 for a well). Fuel, lubricants and mainten-
       ance would cost $1,360 annually for the diesel pump
       and about $200 for the photovoltaic system. Under these
       conditions, the photovoltaic pump would not be competi-
       tive with a diesel pump even if the solar cells were free.
       The photovoltaic system might look better if costs of
       storage and fencing were reduced and diesel fuel became
       more expensive. Apparently, vegetable yields in this
       area are sufficient to make pumping by diesel (but not by
       photovoltaics) financially attractive.

55. WALTON, J.D., Jr.; A.H. Roy; and S.H. Bomar, Jr. 1978.
_A State of the Art Survey of Solar Powered Irrigation
Pumps, Solar Cookers, and Wood Burning Stoves for Use
in Sub-Sahara Africa._ Final Report to Al Dir'Iyyah
Institute. Atlanta: Georgia Institute of Technology,
Engineering Experiment Station. January.

   With respect to solar pumps, notes that a French company,
   SOFRETES, has already installed 36 systems in Africa and
   Latin America. A 1-kw SOFRETES unit costs about $50,000;
   larger systems are $25,000-62,500 per kw, depending on
   size and manufacturer. In an attempt to reduce these
   prices, designers are working on concentrating rather
   than flat-plate collectors, as well as on simpler pumps.
   The authors recommend study of a 2-3 kw system using
   a parabolic dish concentrator based on microwave antenna
   technologies. Such a system might cost about $5,000 per
   installed kilowatt.

56. WEISS, CHARLES. 1976. _Solar Photovoltaic Cells in Develop-
ing Countries._ Science and Technology Report Series No.
26. Washington, D.C.: World Bank. November.

   Summarizes findings of an earlier paper by C. WEISS and
   S. Pak (1976). Notes the prevailing assumption that
   solar cells will necessarily have a long and "trouble-
   free" life. Since experience is as yet insufficient to
   ensure that this is so, manufacturers may need to guar-
   antee their systems for six to ten years in order to
   gain widespread acceptance for solar cells in developing
   countries.

57. WEISS, CHARLES and Simon Pak. 1976. _Developing Country
Applications of Photovoltaic Cells._ Science and Technology
Report Series No. 7. Washington, D.C.: World Bank.
January.

   Concentrates on solar cells to run devices of high (if
   unquantifiable) value: educational television, refrig-
   erators for rural dispensaries, appliances in remote
   tourist hotels. In considering such applications, anal-
   ysts must calculate costs according to actual electricity
   used rather than a system's potential output, since sys-
   tems are unlikely to be fully employed year-round. At
   $20 per peak watt, solar cells for television may be
   competitive both with primary cells and (given very high
   fuel costs) with gasoline generators. At $5 per peak
   watt, solar cells might also find markets for refrigeration
   and tourist uses, as well as being competitive with con-
   ventional power for water pumping in some remote areas.
   Since solar cells involve heavy initial investments,
   buyers in developing countries may require credit from
   suppliers or export banks.

58. WORLD BANK. 1975a. Agricultural Credit: <u>Sector Policy</u> <u>Paper</u>. Washington, D.C.: World Bank. May.

   Notes that "real" costs of agricultural lending (adjusted
   to eliminate inflation) range up to 22% for efficient
   institutions in developing countries. On the other
   hand, real interest rates charged for agricultural
   credit average about 3%. Most of this subsidized
   credit goes to relatively large farmers, leaving small
   farmers to borrow from such sources as moneylenders
   and landlords at real rates of 20-66% or more. To
   meet the requirements of small farmers, there is need
   for decentralized institutions able to provide exten-
   sion and marketing services as well as credit. Also
   useful would be creation of cooperatives and other
   local associations to help administer credit programs.

59. WORLD BANK. 1975b. <u>Appraisal of Lake Chad Polders</u>
   <u>Project, Chad</u>. Washington, D.C.: World Bank. October
   16.

   Considers feasibility of an irrigation project to grow
   cotton and wheat on 1200 hectares of Lake Chad polders.

60. WORLD BANK. 1976. <u>Village Water Supply: A World Bank</u>
   <u>Paper</u>. Washington, D.C.: World Bank. March.

   Most villagers in developing countries lack access to
   safe water, which experts assume is essential for good
   health. Especially in poorer areas, the answer is likely
   to be simple hand pumps to draw water from shallow wells.
   Generally, villagers should pay operating and maintenance
   expenses for these systems, plus at least 10 percent of
   construction costs. For water supply programs to succeed,
   governments will have to provide substantial long-term
   support in the form of subsidies, training, demonstra-
   tion projects, and related services. Since benefits
   from improved public health are impossible to quantify,
   village water projects resemble other "social" activities
   in drawing justification more from national priorities
   than from careful cost-benefit analysis.

DISCOUNT FACTORS

Year	50%	40%	35%	30%	28%	25%	22%	20%	18%	15%	12%	10%	8%	5%	3%	1%	Year
1	.667	.714	.741	.769	.781	.800	.820	.833	.847	.870	.893	.909	.926	.952	.971	.990	1
2	.444	.510	.549	.592	.610	.640	.672	.694	.718	.756	.797	.826	.857	.907	.943	.980	2
3	.296	.364	.406	.455	.477	.512	.551	.579	.609	.658	.712	.751	.794	.864	.915	.971	3
4	.198	.260	.301	.350	.373	.410	.451	.482	.516	.572	.636	.683	.735	.823	.888	.961	4
5	.132	.186	.223	.269	.291	.328	.370	.402	.437	.497	.567	.621	.681	.784	.863	.951	5
6	.088	.133	.165	.207	.227	.262	.303	.335	.370	.432	.507	.564	.630	.746	.837	.942	6
7	.059	.095	.122	.159	.178	.210	.249	.279	.314	.376	.452	.513	.583	.711	.813	.933	7
8	.039	.068	.091	.123	.139	.168	.204	.233	.266	.327	.404	.467	.540	.677	.789	.923	8
9	.026	.048	.067	.094	.108	.134	.167	.194	.225	.284	.361	.424	.500	.645	.766	.914	9
10	.017	.035	.050	.073	.085	.107	.137	.162	.191	.247	.322	.386	.463	.614	.744	.905	10
11	.012	.025	.037	.056	.066	.086	.112	.135	.162	.215	.287	.350	.429	.585	.722	.896	11
12	.008	.018	.027	.043	.052	.069	.092	.112	.137	.187	.257	.319	.397	.557	.701	.887	12
13	.005	.013	.020	.033	.040	.055	.075	.093	.116	.163	.229	.290	.368	.530	.681	.879	13
14	.003	.009	.015	.025	.032	.044	.062	.078	.099	.141	.205	.263	.340	.505	.661	.870	14
15	.002	.006	.011	.020	.025	.035	.051	.065	.084	.123	.183	.239	.315	.481	.642	.861	15
16	.002	.005	.008	.015	.019	.028	.042	.054	.071	.107	.163	.218	.292	.458	.623	.853	16
17	.001	.003	.006	.012	.015	.023	.034	.045	.060	.093	.146	.198	.270	.436	.605	.844	17
18	.001	.002	.005	.009	.012	.018	.028	.038	.051	.081	.130	.180	.250	.416	.587	.836	18
19	.000	.002	.003	.007	.009	.014	.023	.031	.043	.070	.116	.164	.232	.396	.570	.828	19
20	.000	.001	.002	.005	.007	.012	.019	.026	.037	.061	.104	.149	.215	.377	.554	.820	20