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SOME ASPECTS OF RURAL ELECTRIFICATION IN INDIA

Part 1
"Social Cost-Benefit Analysis of Rural Electrification Schemes"

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Part 2
"Cost Effectiveness of Decentralized Energy Systems"

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The views expressed in this report are those of the authors and should not be interpreted as representing the views of either AID or Resources for the Future. Other works on rural electrification supported at RFF include studies in Colombia and Indonesia which complement the India findings. The results from all these reports and the data on which they are based at present are being subjected to further analysis. A comprehensive study of rural electrification that will synthesize this material is planned. Thus this report should be considered as work in progress. It is released with the multiple purposes of informing the energy policy community of the state of knowledge, of stimulating research elsewhere, and of eliciting comments on our own efforts.

EXECUTIVE SUMMARY

The expenses of providing electrical energy to rural areas is an important part of the recent controversy over rural electrification. If electricity was extremely cheap to produce and distribute, then it would be substituted freely for many other types of energy, including wood for cooking. However, extending electricity to rural areas is even more capital intensive than meeting consumer demand in the more densely populated urban regions. Power losses, long high and low tension lines, and transformers are all very expensive items. Because of the scarcity of capital for development projects, the efficient distribution of electricity in rural areas may make the difference between projects that actively stimulate development without creating too much of a financial strain for the utilities, and projects that have minimal development along with producing losses for the utilities.

The Resources for the Future (RFF) rural electrification project has attempted to clarify some of the complex issues surrounding both the costs and benefits of rural electrification. As a result of conflicting reports on the amount of subsidy involved in rural electrification, Indian case studies were conducted to determine the nature and extent of the subsidies for rural electrification. The case study reports were completed by the Administrative Staff College of India (ASCI), and involve detailed benefit-cost analyses using the UNIDO methodology.

The Sixth Five Year Plan of India, covering the 1980-1985 period, provides for a substantial increase in rural electrification, which recognizes the importance of developing small-scale irrigation and achieving accelerated growth of agricultural production. Four million pumpsets were installed by the beginning of the Sixth Five Year Plan. The goal was to electrify 2.5 million additional pumpsets. The outlay on rural electrification provided in the plan is 15.76 billion rupees. The emphasis given to rural electrification by this proposed investment has led to the

present study of rural electrification projects. The first part of the study is a cost-benefit analysis of centralized rural electrification projects, while the second covers the cost effectiveness of decentralized energy systems. Both parts are summarized in subsequent sections.

Part 1
Cost-Benefit Analysis of Centralized Rural Electrification Projects

One unique feature of the benefit-cost study is that the village is the unit of analysis rather than the utility. The advantage of analyzing villages as a unit of analysis is that the cross-subsidies within rural electrification schemes can be examined. In this way village profiles can be constructed according to the changing benefits and costs, thus identifying the villages that are relatively expensive or inexpensive to include in electrification projects, relative to benefits derived.

Cost-benefit studies of rural electrification projects in thirty villages of the Punjab, Maharashtra, and Andhra Pradesh regions were conducted. These states are characterized by distinct cropping patterns, climates, and levels of advancement. Within each state, villages differed according to economic and social backgrounds; farming productivity; number of electrical connections serving the domestic, agricultural, industrial and commercial sectors; population density; distance of village from central grid; and finally the type of benefit resulting from rural electrification projects. In some villages, the only benefit was domestic lighting. In others, crop selection changes occurred from groundnuts to rice, or output of rice, cotton, or wheat increased. The selection of villages with a wide range of characteristics permitted an examination of the sensitivity of the rates of return of rural electrification projects to varying complementary inputs, and made it possible to identify those policies that would tend to make rural electrification projects more profitable.

A financial net present value (NPV) and an economic net present value were calculated for each village. The financial NPV is the difference between the revenue gained from electricity consumers and the present value of capital and operating cost streams of installing and maintaining a distribution network. Providing electricity to rural areas is a

financially viable proposition if the financial NPV is positive.

The economic NPV is the same as the financial NPV except that the value of increased agricultural output due to rural electrification is added as a benefit. To calculate this value added, it is assumed that with rural electrification projects a transition is made from a state of dryland farming with traditional agricultural inputs to a state in which water is available from a central grid electrified irrigation and that modern agricultural inputs are used. Possible intermediate stages of farming using diesel pumpsets for irrigation were discarded, since diesel engines cannot be used for irrigation in all of the same circumstances as electric motors (that is, deep wells). The value added was measured using the following relationship:

$$\text{Value added} = (Q_2 * P - Q_2 * C_2) - (Q_1 * P - Q_1 * C)$$

where:

Q_2 = current output
Q_1 = previous output
P = border price of current output (CIF value of output)
C_2 = border price of fertilizer used per ton of output plus border price of pesticides used per ton of output plus shadow wage rate per ton of output
C_1 = social cost of using manure per ton of output plus shadow wage rate per ton of output

and then adjusted upwards to include a premium on foreign exchange.

Costs of Rural Electrification Projects

The total cost of delivering electricity to individual villages was estimated in two steps. First the marginal cost of bringing electrical energy to the distribution center of the village was estimated. This cost includes the capital and operating cost of generation, transmission, and subtransmission and it is assumed to be the same for all villages. In a second step the marginal cost of distributing electricity from the distribution center to the connections of each village was estimated. This cost varies depending on the characteristics of the village the electricity is being delivered to.

In assessing the first type of cost, this study assumes that the increased supply of electricity will be met by thermal stations. This is a reasonable assumption for three reasons: most of the present demand is met by thermal sources, there are locational constraints in meeting the additional demand from hydro sources, and the government plans to expand thermal energy capacity. The most cost-effective power projects for whom capital costs in 1979-1980 prices were available (Ramagundam and Sangrauli super thermal projects) were chosen to derive the marginal cost of generation, tranmission, and subtransmission. The shadow price of boiler coal used by the thermal stations was computed by identifying the social cost of increasing the mining of average grade coal by one for a pithead coal station. Finally, labor and wage, and operation and maintenance cost was assumed to be 2.25 percent of capital cost. This assumption was based on the desired operational efficiency as spelled out in the project report and on projected expenditures for oil, lubricants, water, wages, salaries, and repairs. Table 1 presents the breakdown in marginal cost of bringing electrical energy to the distribution center.

The cost of distributing the electricity to each village varied depending on the length of high tension lines needed (the further away the village is from the central grid the longer the lines), length of low tension lines (the more scattered the users are the longer the lines), and the number and type of connectors. Thus in order to obtain the total cost of providing electricity to each village, the cost of bringing electricity from the distribution center to the various connections of a particular village was computed and added to the average marginal cost of 38 paise per kWh.

Table 1. Marginal Cost of Electrical Energy Made Available to the Distribution Center

Generation	
Capital recovery to yield 12 percent return	19.00 paise/kWh
Coal cost	4.17 paise/kWh
Labor wages, operations, maintenance, salaries	2.20 paise/kWh
Transmission	4.00 paise/kWh
Subtransmission	1.39 paise/kWh
Cost of Electricity Lost in Distribution	7.24 paise/kWh
COST OF ELECTRICITY AT THE DISTRIBUTION CENTER	38.00 paise/kWh

Results and Policy Implications of the Study

For all but one of the thirty villages the financial NPV computed at the discount rate of 12 percent is negative (see table 2). The value of the financial NPV ranges from Rs. 65,905 to Rs. -796,772. The economic NPV indicator is more favorable, with six villages showing a positive economic NPV and the others showing an economic NPV ranging from Rs. -6,847 to Rs. -277,351. Still, for most villages subsidies that are sometimes substantial are involved in rural electrification projects. A sensitivity analysis of costs and benefits to varying characteristics of villages was conducted in order to devise policies that could reduce these subsidies.

As one would expect, rural electrification projects are more likely to be financially and economically viable when the population served is concentrated, the village is relatively close to the central grid, and the distribution network is optimally laid. A less obvious result is that villages under intensification schemes (those that do not call for the laying of high tension lines or distribution of transformers due to already spare capacity) incur minimum loss. In these villages fifty household connections need to be provided for economic NPV to be zero or positive.

Regional factors also affect profitability of rural electrification projects as shown in table 2. The economic NPV is positive for all villages in Punjab, an agriculturally and industrially advanced state, but negative in the villages of Maharashtra (which is agriculturally and industrially in the intermediate stage) even though the nature of benefit (additional production of rice and wheat) and acres affected are of the same order. Within the Punjab, the most developed regions showed greater economic NPV than the less developed ones. Within Andhra Pradesh, an analysis of an agriculturally advanced area, a drought-prone area, and a backward tribal area shows that (1) the response of the tribal area is below normal because agricultural connections have not been sought from the bulk of the villages; (2) the response in the advanced area is also poor since the area was already benefiting from extensive irrigation, and (3) the response of the drought-prone area is comparatively better and could be improved if the risk associated with the failure of crops in the case of high-yielding varieties of cotton is minimized by state action.

Table 2. Results By Village

Village	Financial NPV (Rs.)	Preliminary Economic NPV (Rs.)
ANDHRA PRADESH		
1. Kambalapadu	-122,409	-113,620
2. Gosanipalli	- 54,965	- 17,551
3. Tallagokulapadu	-146,281	- 71.478
4. Krishnagiri	-195,312	- 45,678
5. Garla Dine	-339,136	+167,216
6. Chittyala	- 81,650	- 6,847
7. Kalagampadi	- 96,858	- 96,858
8. Kerukella	-120,604	-120,604
9. Garikapadu	-277,351	-277,351
10. Megalu	-122,421	-122,421
11. Navarasapuram	-116,558	- 57,263
12. Yenuguvani Lanka	-194,850	-135,555
13. Aritaraf	-155,273	-155,273
14. Beempur	-159,618	-159,618
15. Lachampur	-141,415	-141,415
16. Sangdi	-187,006	-187,006
17. Dharora	-199,778	+239,976
18. Lingi	-155,715	- 53,106
MAHARASHTRA		
19. Chanandru	-155,434	-155,434
20. Meni	-276,279	-276,279
21. Dasak	-345,414	-219,210
22. Manegaen	- 20,791	- 20,791
23. Deethana	-107,398	- 94,878
24. Sarwargaongore	-127,853	-124,532
25. Bhatambia	- 57,674	- 47,711
26. Jawali	-208,797	-172,265
PUNJAB		
27. Sherpur	-796,772	+2,402,615
28. Jessowal	-147,577	+653,024
29. Khirzabad	+ 65,905	+214,854
30. Mainpur	- 22,274	+ 70,819

The amount of land benefiting from rural electrification projects is another factor affecting profitability. The acres to be brought under pumpset irrigation for economic NPV to break even varies with the type of benefits provided (see tables 3 through 5). When the benefit is a switch in cropping pattern from groundnut to rice, about 100 acres must be

affected for economic NPV to turn positive. In the case of a benefit in the form of additional output of rice and wheat, the economic NPV can turn positive when the affected area is about fifty acres. When acres affected are 200 acres, economic benefits can outweigh costs by a substantial margin. Finally, in regions where rural electrification projects permitted an increase in the yield of cotton, it was found that rural electrification projects could be economically profitable even in cases where only ten acres were affected.

Conclusion and Policy Implications

Part 1 of the study finds that in most villages rural electrification projects are not economically or financially viable and must be subsidized by the government. The size of the subsidies is dependent on a number of factors which the study identifies as:

- village characteristics (distance from central grid, population density, number of connections)
- the acreage affected by rural electrification
- the type of benefit expected
- presence or absence of intensification schemes
- extent of other irrigation possible, such as canal irrigation
- the expected response from customers for agricultural connections
- regional factors such as climate and economic level of advancement of the region

To reduce the subsidies involved in rural electrification projects investments for rural electrification projects could first be made in areas where conditions are most conducive to positive financial and economic net present values. Barring factors other than those considered here, this would imply giving advanced areas priority over backward areas. Investments could also be made in drought-prone areas, especially when cheap credit and insurance schemes are available, while investments in regions that already benefit from irrigation could be postponed. Areas with

Table 3. Villages for Which the Nature of REP Benefits Is a Change in Cropping Pattern from Groundnut to Rice

	Financial NPV (Rs.)	Economic NPV (Rs.)	Acres Affected
Kambalapadu	-122,409	-113,620	3
Gosanipalli	- 54,965	- 17,551	13
Tallagokulapadu	-146,281	- 71,478	26
Krishnagiri	-195,312	- 45,678	52
Garla Dine	-339,136	+167,216	176
Chittyala	- 81,650	- 6,847	26

Table 4. Villages for Which the Nature of REP Benefits Is an Increase in Rice or Wheat Production

	Financial NPV (Rs.)	Economic NPV (Rs.)	Acres Affected
Navarasapuram	-116,558	- 57,263	20
Venuguvani Lanka	-194,850	-135,555	20
Desak	-345,414	-219,210	190
Deothana	-107,398	- 94,878	10
Sarwargaongore	-127,853	-124,532	3
Bhatambia	- 57,674	- 47,711	15
Jawali	-208,797	-172,265	55
Sherpur	-796,772	+2,402,615	850
Jessowal	-147,577	+653,024	210
Khitzabad	+ 65,905	+214,854	40
Mainpur	- 22,274	+ 70,819	25

Table 5. Villages for Which the Nature of REP Is Increased Cotton Production

	Financial NPV (Rs.)	Economic NPV (Rs.)	Acres Affected
Dhanora	-199,778	+239,976	30
Lingi	-155,715	- 53,107	7

intensification schemes where at least fifty household connections are provided could be given preference over areas without intensification schemes. Giving priority to areas according to the type of benefit can also reduce subsidies. For instance, higher priority for rural electrification could be accorded to areas growing cotton in view of the substantial decrease in crop failure rural electrification would cause. For other types of benefits the acreage affected by rural electrification could be taken into consideration before an investment is made. As a general rule the greater the area affected the greater the economic net present value will be. When the benefit is a switch in cropping pattern from groundnuts to rice, about 100 acres must be affected for economic NPV to turn positive. The breakeven point when the benefit is an additional output of rice or wheat is less and is approximately fifty acres.

Having considered the costs and benefits of central grid rural electrification projects as well as defined areas where such projects would be most profitable, a question arises as to whether certain decentralized systems for providing electricity might not be more cost-effective than the central grid option. This is the subject of part 2, which is summarized in the following section.

Part 2

Cost Effectiveness of Decentralized Energy Systems

Decentralized energy systems such as biogas, windmills, and solar are possible alternatives to the central grid schemes. Part 2 of this study evaluates decentralized versus central grid electricity on a comparative cost basis. Costs of the nonconventional sources of electricity are based on supplying the proposed requirement for a village as currently met by the Rural Electrification Corporation's conventional system. Costs per kilowatt hours are computed for three villages (Chennapuram, Satulram and Chingapalli) and compared to the cost of providing electricity through a centralized grid system as computed in the "Cost-Benefit Analysis of Rural Electrification Projects." The technique adopted is general enough to allow the evaluation of systems for other villages. Costs are given in 1979/80 price levels and based upon technological development levels prevalent at the time of the study.

Costs were estimated for the following decentralized systems:

1. Biogas system. Biogas plants convert dung and plant residues into methane which is then used to generate electricity. Large systems which would cater to multiple purposes were not considered in this study because of the limited amount of dung available.

2. Horizontal axis windmill. A horizontal axis windmill operates a bore well to pump water without the intermediate stage of conversion to electrical energy. This alternative could be used as an intermediate stage before installing a central grid system. It requires no special fabrication materials, would operate ten to twelve hours per day, and could be used in any location with wind velocity between 6 and 35 kilometers per hour (km/hr).

3. Vertical axis windmill. Unlike the horizontal axis windmill, this the vertical axis windmill would produce electrical energy which could be used for purposes other than pumping water. However, it requires special fabrication materials as well as velocities of 12 to 15 km/hr and could not be installed in all locations.

4. Solar thermal. Radiated heat energy is used to super-heat steam at 500° C. at a pressure of 7 atmospheres to run a steam turbine which generates electricity. A biogas system is used as auxiliary equipment. The main purpose of this system and the one described below is to pump water. However, surplus energy can be stored and used for lighting,

running a drinking water domestic pumpset, or a rice flour mill during nonpeak hours. This is an expensive program being considered.

5. Photovoltaics. Semiconductors use the heat energy to develop voltage to supply electricity.

Sensitivity Analysis

For the three villages analyzed, a sensitivity analysis was conducted to determine how far each village would have to be from the central grid for decentralized biogas systems and centralized systems to be equal in cost. Also considered was how costs for a biogas system would compare with the centralized grid option under the following five different scenarios.

1. Base case. Costs for the base case were derived taking into account the actual consumption of energy for each village as well as other village characteristics such as distance from central grid, type and number of connections, etc.

2. Base case but increased energy demand by 50 percent with an increase in connected load.

3. Base case but increased energy demand by 100 percent with an increase in connected load.

4. Base case but increased energy demand by 50 percent without an increase in connected load. Note that energy demand can be increased without increasing the number of electrical connections if the equipment already available is used more hours per day.

5. Base case but increased energy demand by 100 percent without increase in connected load.

Sensitivity analyses for alternatives other than the biogas system were not conducted. In the case of horizontal axis windmills, this was not done because horizontal axis windmills could never be used as a substitute for a centralized grid since they could not provide electricity for lighting or for highly intensified agricultural or industrial operations. In the case of vertical axis windmills and solar systems, it was not done because under the base case these options were already substantially more expensive than the central grid option.

Results and Policy Implications

Comparative cost results are shown in table 6, and break-even distance at which decentralized and centralized schemes become equally attractive are presented in table 7.

Among the decentralized energy systems considered, the least viable are vertical axis windmills and solar thermal and photovoltaic systems. Vertical axis windmills are more costly than the central grid option and have the further disadvantage that they require a wind velocity of at least 12 km/hr as well as special building materials. Solar energy is even more costly than vertical axis windmills, being up to thirty times more than the base case cost of the central grid option (see table 6). The prohibitively high costs are not surprising since technology for solar energy is still in the development stage. As more is known about the technology, costs will probably decrease, only then will solar energy become a viable alternative.

The most attractive decentralized systems are horizontal axis windmills and biogas plants. The horizontal axis windmill is very cost effective in the sense that the cost of pumping water with the windmill is considerably less than the cost of doing it with any other system (90 paise/kWh instead of 1.90). One must keep in mind, however, that, unlike the other energy devices, a horizontal axis windmill does not generate electricity which could be used for multiple purposes. According to the study, these windmills should be installed as an intermediate solution in villages that (1) have the required wind velocity of 6 to 35 km/hr; (2) where electrification from a centralized grid is expensive; and (3) where the benefit to be repayed through the use of ground water outweighs the installation and operating cost of the horizontal axis windmills.

The cost of providing electrical energy from biogas units is quite comparable to the cost of providing electricity from a centralized grid. Unfortunately, optimizing the decentralized system by designing a larger biogas system for multipurpose usage is limited in scope because of social and cultural fctors and the unavailability of dung in sufficient quantities. Even so, use of biogas plants should be considered when electrical energy demand is relatively low.

Typically, when electrical energy demand is in excess of 15,000 kWh/year, the cost per unit from a centralized system is considerably lower than the cost from any decentralized system. Today, the average annual

electricity consumption for the three villages considered is 10,647 kWh. The response of cost per unit to increased energy demand, particularly with increased connected load observed through various sensitivity analyses, is significant in the case of centralized systems vis-a-vis decentralized systems. However, when the energy demand increase occurs without any increase in connected load, the cost effectiveness of decentralized systems vis-a-vis centralized systems does not appreciably change from the base case and for certain villages biogas plants can be less expensive than the centralized grid option.

Distance away from the central grid is an important factor in deciding which scheme is cheapest. The break-even distance (the distance at which--all other village characteristics being kept equal--decentralized and centralized schemes have equal cost) increases when the demand for energy is increased along with an increase in connected load. In other words, in this particular scenario, a centralized grid can be more attractive than a decentralized system even for villages located far from the central grid. However, when energy demand increases without an increase in connected load, this is no longer true; the break-even distance comes down marginally.

In summary we can say that biogas plants are the most viable alternative to the centralized grid option. These are likely to be cheaper in villages where electrical energy demand and number of connections is low and where distance from the central grid is great. However, for the final decision to be made, costs must be computed for each particular village since other factors also influence cost.

Table 6. Results Summary (Rs. per kWh in 1979/80 prices)

	Chennapuram	Satulran	Chingapali
1. Centralized grid supply			
a. Base case Actual consumption of energy for each village, other village characteristics such as distance from central grid, type and number of connections	1.85	2.05	2.45
b. Base case but increased energy demand by 50% along with increase in connected load	1.57	2.20	1.99
c. Base case but increased energy demand by 100% with increase in connected load	1.42	1.97	1.76
d. Base case with increased energy demand by 50% but without increase in connected load	1.36	na	1.76
e. Base case with increased energy demand by 100% but without increase in connected load	1.12	na	1.42
2. Decentralized grid system Biogas system			
a. Base case	1.96	1.80	2.06
b. Base case but increased energy demand by 50% along with increase in connected load	1.39	1.77	2.02
c. Base case but increased energy demand by 100% with increase in connected load	1.37	1.75	2.00
d. Base case with increased energy demand by 50% but without increase in connected load	1.39	na	1.31
e. Base case with increased energy demand by 100% but without increase in connected load	1.09	na	1.23
3. Decentralized grid system Windmill-horizontal axis (intermediate solution)	0.90	0.90	0.90
4. Decentralized grid system Windmill-vertical axis	3.27	3.27	3.27
5. Decentralized grid system Solar thermal (approximate cost)	62.00	62.00	62.00
6. Decentralized grid system Photovoltaic (approximate cost)	21.00	21.00	21.00

Note: na = not available

Table 7. Results Summary: Break-Even Distance*

	Chennapuram	Satulran	Chingapali
1. Base case	1.55	0.40	1.10
2. Base case but increased energy demand by 50% with increase in connected load	2.50	0.80	1.80
3. Base case but increased energy demand by 100% with increase in connected load	2.30	1.20	2.60
4. Base case with increased energy demand by 50% but without increase in connected load	1.48	na	1.20
5. Base case with increased energy demand of 100% but without increase in connected load	1.39	na	1.10

Note: *Break-even distance in kilometers from high tension lines beyond which decentralized biogas system is attractive.

For Satulran village computations have not been carried out for cases without increase in connected load as the bulk of connections are for domestic lighting.

Part 1

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R. Venkatesan

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Chapter 1

INTRODUCTION

The Rural Electrification Program: History and Status

Projects for distributing electricity to rural areas of India formally began only after 1950. The main thrust of rural electrification was to supply power for minor irrigation. Progress in the 1960s was meager; at the end of Third Development Plan (1966), 45,000 villages out of a possible 576,000 (roughly 8 percent) had electricity, and a total of only 500,000 pumpsets had been energized. The drought of 1965-1967 was the catalyst for increased rural electrification and in the period 1966/67 to 1970/71 roughly Rs. 4.5 billion were invested on rural electrification, surpassing the cumulative expenditure on rural electrification during the first three national plans. Of late, increased attention has been paid to supplying power for agroindustries.

Investments in rural electrification projects before 1979 are shown in table 1-1. A breakdown of investments by scheme is shown in table 1-2. An analysis of these two tables reveals that the investment in rural electrification schemes has been about Rs. 7,500-9,000 per irrigation pump at 1979 prices. The analysis also reveals that the principal investment factor is the number of agricultural connections per village. This rough analysis indicates that budget allocations for rural electrification schemes are best arrived at by examining the number of connections to be given rather than the number of villages to be electrified. In fact, the Reserve Bank of India had proposed a program to energize 3,000,000 pumpsets during 1978-1983 in participative arrangements with Rural Electrification Committe (REC). Given the fact that it costs about Rs. 9,000 per connection, the magnitude of investment involved warrants a detailed social cost-benefit study of Rural Electrification Projects (REP).

Table 1-1. Investments in Rural Electrification Schemes

Plan period	Villages electrified at end of of plan period	Pumpsets energized at end of of plan period	No. of additional villages electrified	No. of additional pumpsets energized	Average no. of pumpsets per village (5:4)	Outlay in current prices (Rs. 10^7)	Outlay in constant '79 prices (Rs. 10^7)	Outlay per additional village (current prices)	Outlay pumpset (current prices)	Outlay/ village (constant 1979 prices)	Outlay/ pumpset (constant 1979 prices)
1	2	3	4	5	6	7	8	9	10	11	12
1951-56	7,296	56,056	4,233	35,056	8.3	8	27.8	18,900	2,282	65,819	7,930
1956-61	21,750	198,904	14,456	142,848	9.9	75	244.5	51,881	5,250	169,448	17,116
1961-66	45,144	512,756	23,394	313,852	13.42	153	461.2	65,401	4,874	196,900	14,964
1966-69	73,732	1,088,804	28,588	576,048	20.15	237	440.6	82,901	4,114	154,490	7,648
1969-74	156,729	2,426,133	82,997	1,337,329	16.11	783	1,304.5	94,340	5,854	157,174	9,754
1974-79	232,042	3,599,328	76,313	1,173,195	15.37	743	846.3	97,362	6,333	111,080	7,263

Note: 1. To get outlay in constant prices, deflators from National Income Statistics were used.

2. An examination of columns 11 and 12 reveals that investments in rural electrifiction projects are a function of the number of agricultural connections given outlay per village changes depending on the number of agricultural connections provided.

Source: Rural Electrification Panel, Committee on Power, September 1979.

Table 1-2. Investments in Rural Electrification, By Scheme

Year	Scheme sanctioned (in numbers)	Current prices	Constant 1979 prices
1969-70	11	5.70	10.26
1970-71	94	65.73	115.36
1971-72	114	66.90	111.58
1972-73	226	100.17	149.26
1973-74	254	76.97	96.35
1974-75	302	132.98	143.83
1975-76	283	111.94	127.50
1976-77	331	102.35	108.85
1977-78	399	138.60	142.59
1978-79	716	219.11	219.11
1979-80	770	215.26	215.26
	3,500	1,237.51	1,439.95

Note: The 3,500 schemes included 2,992 area electrification schemes, 75 special transmission schemes, 201 systems development schemes, 187 Harijan Basti schemes, and 43 schemes for lineman training. Capital investment/scheme in 1979 prices works out to Rs. 4.1 million. If we only take area electrification schemes into account, the investment needed per pumpset works out to Rs. 9,000. Average investment per electrified village works out to Rs. 72,500.

Source: Reports submitted to the Power Committee, mimeo, 1980.

Potential for Rural Electrification Projects With a Bias toward Small Scale Irrigation

By 1979, roughly 39 percent of total villages in India had been electrified, and about 3.5 million irrigation pumps had been sunk. Another 20 million hectares of potential ground water--36 percent of estimated total ground water reserves--is yet to be tapped. Roughly 45 percent of pumps energized lie in Tamil Nadu, Haryana, Punjab, and Andhra Pradesh, which account for only 22 percent of ground water potential. Roughly 52 percent of ground water potential is located in Uttar Pradesh, Bihar, West Bengal, Assam, and Orissa, but the regions account for only 14 percent of total number of pumpsets energized. The fact that such potential for rural electrification projects for small scale irrigation still exists and that huge investments are likely to be made on rural electrification schemes

emphasizes the need for detailed socioeconomic impact studies of rural electrification.

Organization of the Part 1 Report

Chapter 2 examines the need for carrying out a social cost-benefit analysis and variants of analyses are discussed. Chapter 3 briefly reviews cost-benefit studies on rural electrification carried out in the recent past. Chapter 4 dwells on methodology adopted for analysis and chapter 5 analyzes the results and brings out the policy guidelines to maximize social profitability.

Chapter 2

SOCIAL COST-BENEFIT ANALYSIS: NEEDS AND VARIANTS

Introduction

Social cost-benefit analysis can be defined as the evaluation of a project's contribution to the objectives of the government. Traditionally, project appraisal dealt with efficiency aspects of resource allocation; of late, the income distribution aspects of projects are increasingly analyzed as governments begin to use project selection as a strategy to attain better intra- and inter-temporal distribution of income.

The Need for a Social Cost-Benefit Analysis

Social cost-benefit (SCB) analysis may not be warranted if:

1. market prices equal social prices, since decentralized investment, production, and consumption decisions made on this basis will be socially optimal;

2. market prices of goods and factors do not equal the marginal social cost (MSC) or the marginal social value (MSV) of using relevant goods or factors, that is, if the domestic government does not consider income distribution as an important objective; or

3. equitable income distribution is considered a prime objective, and the government elects not to use the strategy of project selection. The government may rely on neutral fiscal measures to decrease disparity in income, increase domestic savings, etc.

Need for SCB analysis of a project in the Indian context is best determined by examining the objectives set forth in the most recent national development plan document (Government of India, Planning Commission, 1981). The plan document lists the attainment of social

justice along with growth as one of its prime objectives. The objective of social justice as articulated in the plans has two major dimensions: (1) improvement in the living standards of the poorest groups in society, and (2) reduction of inequalities in asset distribution. The government has also chosen project selection as a strategy to attain intra- and inter-temporal distribution of income and has for this specific purpose set up a Project Appraisal Division (PAD) within the Planning Commission. The divergence between market and social prices seem to indicate that these divergences are due to taxes, duties, and controls on foreign trade.

The need for an extensive rural electrification scheme within the national development plan could stem from one of the following reasons:

1. Rural Electrification Projects (REP) emphasizing small scale irrigation may affect inter- and intra-temporal distribution of income.

2. REP with some emphasis on the small scale irrigation projects may be preferred if at margin the country is a regular importer of food grains or if the country entails enormous expenditures at times of grain scarcity due to the price inelasticity of demand for food grains;

3. REP may be preferred if it can be proven that increased agricultural production reduces rural poverty; or

4. If none of the above three conditions are valid, government may consider providing electricity to rural areas as a 'basic' scheme and may be examining the least cost method of achieving the objective.

However, rural electrification projects do not fall under the 'basic' project category since postponement or rejection of electrification need not lead to disaster as would be the case with rural water projects in drought-prone areas. Farms and households can use substitutes. Thus the justification for REP should stem from the other points. There is evidence that the incidence of rural poverty declines with increasing agricultural output (Ahluwalia, 1976). Also, India has been a regular importer of food grains. In fact, only twice in the past thirty years has India been able to build a buffer stock of food grains above the current year's operational needs. Bad harvests have necessitated at least minimum grain imports to maintain public distribution and desired per capita consumption. Bad

harvests have also destabilized the economy by causing unstable grain import bills. Following lean harvests, grain imports have had a priority claim on foreign exchange, thus reducing imports of other commodities. This proved economically disruptive and costly, and food grains imports often were held below the level that would have avoided an undesired price rise on the domestic market.

Thus the need to carry out REP is clearly established even though REP does not qualify as a basic project. Since the government has chosen the strategy of project selection to affect intra- and inter-temporal distribution of income, REP can be effectively used (along with credit measures for marginal farmers and landless laborers' cooperatives) to distribute income among the roughly 80 percent of the country's population which lives in rural areas. Clearly, study of the design and implementation of rural electrification schemes would clarify how much the REPs can contribute to achieving the objectives set forth by the government in its plan document.

Variants of SCB Analysis

The two principal methods of analyzing projects for social profitability are as follows:

1. the United Nations Industrial Development Organization (UNIDO) methodology as set out in John Hansen's Guide to Practical Project Appraisal and reinterpreted in a recent United Nations publication by John Weiss entitled Applications

2. Little and Mirlees' (L&M) approach as interpreted and modified by Squire and Van der Tak.

These two approaches are the same in principle in that they are forms of applied welfare economics and they treat the values of foreign exchange, savings, and unskilled labor as crucial sources of a distorted price mechanism and carry out corrections in a similar manner. The significant differences in the two approaches are as follows:

1. The yardstick (numeraire) for measuring social valuations is the uncommited social income in free foreign exchange held by the government in the Little and Mirlee approach.

while it is the aggregate consumption of the income group, corresponding to the critical consumption level, in the case of the UNIDO approach. The cut-off discount rate used in the analyses are the accounting rate of interest (productivity of current investments in terms of the L&M numeraire) and the consumption rate of interest, respectively (weight placed to future consumption relative to current consumption).

2. The L&M method, in deriving shadow prices, uses explicit multiple conversion factors which correspond to the extant multiple exchange rates, while the UNIDO approach uses a mean exchange rate averaged across the effective multiple exchange rates on the trade commodities. However, the modifications provided in the Guide allow for evolving adjustment factors by decomposing non-traded goods into their tradeable goods and primary factor components. The original Guidelines numeraire was not considered neutral. However, the modifications suggested in the Guide allow for valuing all changes in consumption in terms of 'equivalent' consumption at the hands of income groups at the critical consumption level. A recent modification is to treat government savings and private savings at par with government consumption, as set forth in Applications.

3. The L&M approach assumes a strong project appraisal function, while the UNIDO approach assumes that a realistic planner cannot and will not challenge the decision makers.

Reasons for Choice of UNIDO Method

This study has adopted the UNIDO approach of SCB analysis. The Guidelines method is carried out in five stages, each of which leads towards a measure of social benefit of the

1. Calculation of financial profitability at market prices

2. Shadow prices of resources to obtain the net benefit at efficiency prices

3. Adjustment for project impact on savings and investment

4. Adjustment for project impact on income distribution

5. Adjustment for project production or use of goods such as luxury consumer goods and basic needs whose social values are less than or greater than economic values.

A major advantage of the stage by stage method is that the desirability of a project can be measured for different objectives. Also, if the availability of data is a constraint in carrying out analyses in any stage, the analyses can be stopped at the intermediate stage and results can be conveyed to the decision maker. Hence, one of the prime reasons for choosing the UNIDO method was to use the stage-by-stage approach instead of summarizing all the impacts by using some weighting scheme.

Secondly, the project appraisal function as perceived in India is not expected to challenge the decision makers.[1]

To summarize, the advantages of using the stage-by-stage approach and the realistic role of planning function as assumed in the UNIDO approach are the principal reasons for choosing the UNIDO methodology to appraise REP.

Parameters Used for Project Evaluation

Table 2-1 lists the values of parameters used in the cost-benefit computations. For a more detailed look as to how these were estimated, refer to appendix B.

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1. Deepak Lal, "Prices for Planning," 1980, p. 32: "The current thinking in the PAD is not to attempt to question plan targets but nevertheless to present economic rates of return for projects in the plan, to those setting plan targets, so that these may be reappraised in the light of economic rates of return."

Table 2-1. Summary of National Parameters

Parameter	Probable value	Remarks
1. Shadow Exchange Rate (SER)	1.25	SER is 1.25 times the official exchange rate
2. Marginal Productivity of Capital (q)		
Estimate[1]	0.20	Using ICOR for the economy as a whole
Estimate[2]	0.12	Considering only the modern sector
3. Consumption Rate of Interest (i)	10-11%	11% assumed for the study to have a plausible P_{INV} value
4. Elasticity of Marginal Utility to Increased Consumption (e)	3	Obtained indirectly as a mutually consistent value of CRI, growth rate, etc.
5. Global Marginal Propensity to Save (MPS)	0.34 to 0.40	0.40 assumed for the study
6. Global Marginal Propensity to Consume (MPC)	0.60	Obtained at (1 - MPS)
7. The Overall Social Value of Investment in terms of Consumption (P inv)	1.32 to 2.56 for range of 'i' - 11-8%	1.32 has been assumed for the study
8. Shadow Wage Rate (SWR)	0.60	Equal weight has been given to agricultural workers' consumption and the consumption of the government
9. GINI Coefficient (GINI)	0.28	
10. Distribution of Consumption Parameter	2.29	
11. Global Distribution Weight (d)	1.68	
12. Per Capita GDP in 1979/80	Rs. 1,484/year	
13. Critical Consumption Level		
Estimate	Rs. 1,374	Based on D
Estimate	Rs. 1,365 to Rs. 1,068/year	For P inv values of 1.29 to 2.56
Estimate	Rs. 647/year	Poverty level estimate (this has been used for the study)
14. Period to attain optimality in savings rate	50 years	
15. Accounting rate of interest	12%	

Chapter 3

REVIEW OF THE LITERATURE

Introduction

Available literature agrees that the main problem for rural electrification lies in the high cost of line construction, which necessitates the imposition of high rates for rural electrification schemes to be financially viable in areas of low consumer density, and which can reduce demand for electrical energy. Thus, there is considerable interest in the ongoing research work on the economics of decentralized energy systems as an alternative to power supply from the main grid.

While the available literature agrees on the nature of the problems, there is considerable difference of opinion on the measurement of costs and benefits. The methodologies for measuring social costs and benefits also differ in scope.

Consequences of Rural Electrification

The consequences of ´productive´ use of electricity in agriculture, poultry operations, dairy farming, cattle operations, and rural industries are listed below:

Increase in productivity
Increase in production
Increase in quality of products
Reduction in costs
Reduction in seriousness of machinery breakdowns
Reduction in fire hazards
Lengthening of the effective work day
Increases in dependability with consequent decrease in losses
Increase in security
Reduction of uncertainty of marketing the product on account of new processing industries
Improved credit availability on account of more skilled people agreeing to move to the electrified villages.

Lighting is referred to in the literature as the most important domestic use of electricity. The consequences of 'domestic' use of electricity are stated as improvement of health (through the availability of drinking water), education, and sanitation.

Measurement of Costs and Benefits and Methodologies of Social Cost-Benefit Analysis

The methodologies commonly employed in evaluating rural electrification schemes can be broadly classified under three approaches. In one approach, benefits and costs and net benefits and costs are enumerated in detail. Contingent estimates to take care of indivisibilities, externalities, and imperfections are provided. In the other approach, the costs of rural electrification are compared with those of other methods of providing similar facilities and the net benefits are thus estimated. Yet another way of assessing the economic value of rural electrification reported in the literature is to measure the value of land before and after electrification. It is argued that the time profile of benefits streams will dictate the land value and thus the land values can be used as proxies for economic value of rural electrification.

Most of the available literature defines the financial cost-benefit analysis from the viewpoint of the national electricity board, and that of social cost-benefit (SCB) analysis from the viewpoint of customers/society as a whole. The available literature is vague about the enumeration of social benefits, for it does not discuss how the benefits to society or consumers (even assuming that the customers are a homogeneous mass) can be translated to gains of economy. The concept of reference consumption level (the consumption level at which a rupee accruing to the private sector is regarded to be the same as that accruing to the government), is conspicuously absent in all the available literature. It is not clear how the benefits to society and the government are integrated without these specific measures. Also, income distributional effects are not dealt with in sufficient detail. The only analysis that touches on the subject briefly mentions the positive correlation between the size of land holdings (a proxy for income level) and the benefits accruing from rural electrification, thereby implying that income distribution is adversely affected by rural electrification schemes. These viewpoints are critically

analyzed here to test their adoptability and to devise a suitable methodology for the present study. Care has been taken to analyze only the major works in the area.

Helio Mattar (1976) uses the increase in land value in the area directly affected by the rural electrification project as a proxy for the measure of economic benefits derived from the project. He makes an assumption that the project would be economically marginal in relation to the economy of the outside world. In the analysis, he initially shows the relationship between the benefits and economic surplus generated by the use of electricity at the farm level. An analysis of the productive demand for electricity at the farm level accounting for the monetary benefits yields results in terms of an increase in land rent. Results are then derived for the case of consumptive demand for electricity. The study states that the main part of the benefits which may not be considered in the increase in land value is that which accrues to the producers of electricity in cases where the price being charged for electricity does not equal its marginal cost.

An econometric model using cross sectional data is then proposed for the purpose of predicting increases in land value. For the purpose of application of the model, the area of study is divided into quasi-squares for each of the variables being calculated.

The proposed variables attempt to account for differences among the squares in soil and topography, climate, transportation characteristics and electrification. The variables proposed are: (1) a land capability index, defined to be the proportion of land equivalent in terms of production capacity to class I land (according to the land capability classification) in a square which accounts simultaneously for soil and topography differences; (2) a water deficiency index, defined to be the annual difference between potential and real evapo-transpiration in a square which accounts for climate as a limiting factor; (3) an internal accessibility index, defined in terms of the existence of transpiration flows among nodes inside and in the periphery of the area of study which accounts for differences in the transpiration economic interdependence inside the area of study; (4) an external accessibility index designed to be sum of the inverse of trip costs to large markets external to the area of study--which account for

differences due to the distance of each square to the external markets; and (5) an electrification index, defined to be the number of kilometers of rural electric power primary distribution lines per square kilometer in a square and corrected for differences in the average size of farms among the squares to account for differences in the coverage of the electric power distribution network among the squares.

Two alternatives to the land capability index are defined for the case in which land capability maps are not available: (1) a quality of soil index, defined to be the percentage of equivalent best land inside a square, according to a subjective grade given by a soil expert, and (2) a topographic index, defined to be the number of times the diagonals of a square hit 20 meter contour lines. Through the use of these variables an attempt to model the behavior of the rural land market has been made, the variables being surrogates for the characteristics analyzed by the market in the process of rural land price formation. In the next section the adoptability of an econometric model to measure economic benefits is briefly reviewed.

The basic hypothesis that the increase in land value in the area directly affected by the project is a proxy for measurement of economic benefits has drawbacks, especially in the context of developing economies where imperfect capital markets exist. Also, the basic aim of the study is to examine the income distributional aspects of rural electrification; these are totally ignored in the above derivation of economic benefits. A model will be less applicable when the bulk of the rural population consists of landless laborers for whom the increase or decrease in land value may or may not make any material difference.

However, Helio Mattar's study throws light on the relevant variables that affect output from farms and the magnitude of their impact. The National Council for Applied Economic Research (NCAER, 1967, 1970) in its two published studies on the economics of rural electrification elaborates the methods used to measure cost and benefits.

The studies proceed from the basic premise that (1) lift irrigation is the backbone of intensive irrigated agriculture in India, and (2) rural electrification is a very essential supporting program providing electric power for lift irrigation. The NCAER study (1970) found that the main demand for electrical energy in Kerala was for lights and fans and

comparatively very little was for pumpsets for irrigation. The results indicate that in states endowed with heavy monsoon rains, such as Kerala, there is no motive for tapping subsoil water.

As regards the impact of the use of electricity in agriculture and industry in Punjab, the study revealed that there was a distinct change in the cropping pattern and improvement of productivity of land with the advent of electric pumpsets. The study also found that the value of additional output from industries as a result of electrification was not significant although the industries sprang up only after electrification of rural areas.

The studies attempt to measure the economic benefits arising from rural electrification as the incremental benefit (or put alternatively, reduction in costs) over pursuing alternative methods of increasing productivity. However, the NCAER study suffers from the serious drawback that market prices for inputs and outputs are used to calculate the economic benefit-cost ratio. Particularly when fertilizers are heavily subsidized and the price of output is state-controlled, value-added at market prices does not reveal the value-added in efficiency prices. Also, the difference in the cost of operating a diesel pumpset over an electric pumpset cannot be taken as benefit arising due to rural electrification if the effect of the pumpsets in irrigating lands is not the same. Also, when there are significant price differences between diesel and electric pumpsets (in one time capital cost and recurring operating costs) it is naive to expect that farmers will resort to diesel pumpsets in the absence of electric pumpsets.

The incremental benefits arising out of the increased productivity of land irrigated by pumpsets as opposed to traditionally irrigated land are more indicative of benefits arising out of rural electrification than are cost savings arising out of use of efficient electric pumpsets over diesel pumpsets since the response of farmers to adopting diesel pumpsets (next best alternative) is very poor.

Yet another study which addresses the problem of measurement of economic benefits arising out of rural electrification is that of Ross (1972). Ross based his results on pre-electrification surveys in Colombia and Nicaragua and attempted to compute a benefit-cost ratio for these projects. He attempted to compute the increase in value-added by the farms

to GNP arising out of rural electrification. For instance, if value-added[2] computed for the base year is 'Vd' then he computes the incremental value-added due to electrification as the increase in value-added over the base year and uses the present value criterion to judge its economic attractiveness. The market rate of interest is used to discount benefits and is then compared with the capital cost of the project.

The study, of course, uses the appropriate criterion for selection of rural electrification of projects through the use of present value criterion. However, the basic assumption that the ratio of inputs other than energy remain the same after electrification is not valid, and predicting results from pre-electrification survey has drawbacks. Moreover, it does not attempt to correct for price distortions in prices of inputs or outputs. Neither does it attempt to measure the income distributional aspects.

Yet another study which attempts to measure benefits and costs through systems analysis is that of Patil and coauthors (1976).

The study has a different focus:

1. It looks at the financial viability of schemes proposed through projected cash flow statements, listing yearly cash deficits and arguing for establishing appropriate yardsticks for electricity boards to evaluate rural projects.

2. It critically examines the load build-up cost elements in setting up distribution lines and the various assumptions that go in the computation of financial rate of return.

3. It makes a critical survey of methods of assessing ground water potential. and their implications for assessing the financial viability of the schemes.

4. It critically examines the cluster schemes and arrives at the minimum density of customers required so that at the existing financial rates the schemes break even.

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2. Value-added as used by Ross is

$$G - (L + e + VI)$$

where

G = Gross output of the firm
L = Labor costs
E = Energy costs
VI = Variable input costs

Although this financial analysis of schemes has limitations for the present study, it provides an insight into the variables that affect the success of schemes and the important technical parameters assumed for calculating financial viability. The effect of the above mentioned variables on social profitability has been carefully included in the present study.

The cost-benefit studies done by the Rural Electrification Corporation (REC) (1979) in Tamil Nadu and Uttar Pradesh are immediately relevant to the present study. The terms of reference of the studies have been (1) to analyze the investment in and return on rural electrification projects, and (2) to assess the direct and indirect costs and benefits to the society as a whole of electrifying wells and setting up processing industries.

The financial analysis part of the study has been done from the perspective of the state electricity board, while the other part of the study has been carried from the view point of the society.

In the study carried out in Tamil Nadu, the study group assumes the investments made by the Tamil Nadu Electricity Board (TNEB) as public investments and the investment made by the farming community as private investments. The study considers the components of capital cost as follows: (1) high tension (HT) lines and low tension (LT) lines, (2) distribution transformers, (3) service connection costs, and (4) overhead. Under operating cost, the cost of energy to the consumers, interest on capital, and the operation and maintenance expenditure of electrical extensions have been included.

The study assumes the transmission and distribution loss at 12 percent and includes the cost of energy loss as part of the energy cost. The study identifies the private costs as costs incurred by the farmers, namely: (1) cost of well and pump house; (2) electric motor and pumps; and (3) installation charges. In a similar fashion, private costs of small entrepreneurs are: (1) cost of land and building, (2) electric motor and equipment, and (3) installation of electrical equipment. The study identifies private benefits as the incremental benefits accruing to farmers and industrialists consequent to electrification.

The studies argue that cost savings over use of the next best alternative (diesel pumps) cannot be included as an incremental benefit because diesel pumps cannot be used to tap water from deep wells and

therefore are not an alternative. This view, coupled with the earlier observation that farmers do not adopt diesel pumps to the same degree as electric pumps, has prompted us to compute the financial and social benefits as the value-added in incremental production rather than the savings in cost in alternate modes of operation.

A major deficiency of the study is that it attempts to evaluate benefits and costs in current prices rather than in constant prices, using the discount rate to compute the present value which does not include any margin for inflation. Moreover, the concept of social cost-benefit analysis as the incremental benefit to society (as though the society is wholly homogeneous) is yet another flaw of the study.

While the REC study, namely, Benefit-Cost Ratio of Rural Electrification Schemes in Ghazipur in Uttar Pradesh, also suffers from the same conceptual deficiencies, the two studies yield considerable information on norms for planning capacity expansion, the computations of connected load norms for requirement of distribution transformers, etc. The field data of various studies have been collected, analyzed, and along with the present study's field data used to make appropriate assumptions regarding the various technical parameters.

Detailed work on the impact of rural electrification on small scale irrigation and rural employment at the conceptual level has been carried out by Balwanth Reddy (1979). He finds that small scale irrigation has a significant impact on employment; the size of the impact varies with the region.

On average, he estimates an increase in employment of about two months per person for an increase of one irrigated acre under small scale irrigation. He finds the effect of electrification on employment to be positive as it has led to more intensive cultivation of land. The other variables which influence employment are area under small scale irrigation and credit. He concludes that if electrical energy use leads to more intensive cultivation of land or to an increase in area under small scale irrigation, then with an increase in available credit the impact on employment will be significant.

The study of costs and benefits of rural electrification in Andhra Pradesh by the Administrative Staff College of India (ASCI, 1980) has two distinct features for an evaluation of rural electrification schemes.

While all the studies are based on gross value of capital stock of rural electrification schemes as shown in books, this study considers annualized capital expansion costs expressed in prices of a selected base year as the correct indicator of the costs to be incurred. This, the study argues, is the long-run marginal cost of generation, transmission, and distribution, rather than average costs.

Secondly, it estimates the net benefits of rural electrification at three different and distinct levels, namely, the users, the electricity authority, and the economy or community as a whole. The study considers a mix of thermal and hydroelectric projects (a ratio assumed to be same as current mix of generation) for the estimation of generation costs.

While the annualized capital expansion costs has been considered as a long-run marginal cost, only thermal power plant capacity expansions costs have been used in this study. Logically, the demand for electrical energy at any given place can be met only through increased supply from a thermal generation source. Since electrical energy is regarded as a non-tradeable without any supply constraints and since locational constraints come in the way of capacity expansion in hydroelectric projects, this study assumes that appropriate annualized capacity expansion costs to be used will be that of only thermal power plant capacity expansion costs. Also, the present study evaluates the social benefits at the reference income group level (defined as the income of the people at poverty line based on a particular base year prices) and uses the shadow prices for evaluation of inputs and outputs rather than market prices.

Chapter 4

METHODOLOGY OF ANALYSIS: AN OVERVIEW

Introduction

Ideal planning involves the problem of allocating scarce resources (both intra- and inter-temporal) to maximize social welfare, given resource constraints and technological possibilities.

The resource constraints include institutional constraints, and the technological possibilities include trading possibilities. In principle the optimal solution to the allocation problem will determine the optimal inputs and outputs and hence the optimal production and investment program as well as the associated dual prices (interpreted as social prices). It would be theoretically desirable to evolve an ideal plan and associated dual prices (social prices) but it may not be feasible to evolve such a plan in practice. Also in real life the projects are submitted for approval one by one. It then becomes necessary to classify public sector projects into basic and non-basic projects. Basic projects are those for which explicit production targets are laid down and the project appraiser does not question the need to produce the output. Instead the appraiser seeks to analyze the cost effectiveness of the chosen path of meeting the target. For non-basic projects, the option to make or buy is relevant and there are no sectoral constraints. Both the costs and benefits of domestic production, vis-a-vis the alternatives of importing or allowing shortages to prevail will have to be analyzed.

This study assumes that provision of electricity to rural areas falls in the non-basic category as it can be delayed, whereas a basic projet, for instance, provision of rural drinking water, cannot. Precisely for this reason a detailed social cost-benefit analysis is done and the types of

rural electrification strategies needed to maximize social benefits are identified.

Under the above circumstances an effective selection criterion has to be made which is not complicated and provides a reasonable approximation. In this study, if a project involves production of a tradeable good, then the return on capital employed has to be compared with the test discount rate (in this case the social discount rate). If the project involves production of a non-tradeable good, then the cost of meeting the demand from the project has to be compared with a project belonging to the cost minimization set. If it is a non-basic project producing a non-tradeable, then shortages are allowed to occur until a project belonging to the cost minimization set is presented to the decision maker.

Cost of Electrical Energy

Since electrical energy is a non-tradeable good without any supply constraints, demand for electrical energy at the margin has to be met by an increased supply. This study assumes that an increased supply will be met from thermal stations instead of a hypothetical mix of hydro, thermal, and nuclear stations for the following reasons:

a. The bulk of the current demand is met by thermal sources and there are locational constraints in meeting the additional demand from hydro sources.

b. The government plans to expand thermal energy capacity by setting up new super thermal stations (roughly up to 2,100 MW) in Singrauli, Korba, Ramagundam, Farakka, Talcher, Waldeim, Pench, Kahalgam, and Mange.

Since additional supply is likely to be from thermal stations and since it has been identified that super thermal stations are likely to be the projects belonging to the cost minimization set, the cost of generating electrical energy in one of these stations is likely to be the reference social cost. That is, annualized capacity expansion costs, expressed in base year prices (that is, long-run marginal cost) along with operating cost of fuels, other supplies, and wages, will be the cost of electrical

energy to be used for computations. Care has been taken to include capacity expansion costs of sub-transmission along with allowances for loss of electrical energy up to the sub-transmission and distributional stages as a part of the energy cost.

Thus the capital cost of providing electricity to rural villages is the cost involved in the setting up of the distribution system, namely, capital cost of distribution transformers, high tension lines, low tension lines, and service connection charges. The operating cost of providing energy is the cost of electrical energy computed in the manner as described in the previous section. Clearly, priorities in setting up distribution transformers, the maximum cluster of customers required, etc., can be decided by comparing the cost with the benefits expected out of rural electrification.

Benefits of Rural Electrification

We might represent the state of use of traditional agricultural inputs in dryland farming as A, the state of use of traditional agricultural inputs in diesel irrigation as B, the use of modern agricultural inputs in conjunction with central grid electric pumpset irrigation as F as shown in the table below. This study assumes that benefits arising out of electricity to rural areas are equal to the incremental benefits arising out of transition from state A to state F.

Table 4-1. Analysis Possibilities

	Dryland farming	Diesel irrigation	Central grid electrical irrigation
Traditional agricultural inputs	A	B	C
Modern agricultural inputs	D	E	F

The reasons for assuming that transitions from state A to state F take place are as follows:

1. If this were not true then with the introduction of electricity to rural areas, logically, there must have been conversion of diesel pumps to electric pumps or discontinued use of diesel pumps in favor of electric pumps which had not been the case.

2. Technical problems arise when using diesel pumps to tap water from deep wells which are not encountered when electric pumpsets are introduced.

3. When the cost of installing and running a diesel pump is significantly higher compared to electric pumpset, in some circumstances farmers will not use diesel pumpsets in the absence of electric pumpsets.

In fact even in the case of a crop such as cotton, which is perceived (by farmers) as ´risky´ as non-availability of water during the critical period can mean a significant loss, there was reluctance to use diesel pumpsets to assure water supply.

While theoretically operating a diesel pumpset may be the next best alternative to running an electric pumpset, this study assumes that the benefit of providing rural electricity can be thought of as moving from dryland farming with traditional agricultural inputs to farming with a central grid irrigation system and modern agricultural inputs. However, it can be argued that the benefit of increase in yield resulting in transition from state A to state F cannot be attributed solely to agricultural pumpsets as a portion of this has to be attributed to the use of high-yield seed varieties, fertilizers, and pesticides.

The fallacy in the above argument is as follows: Since the inputs, such as high-yielding seed varieties, fertilizers, pesticides, etc. are tradeable and hence accessible to farmers, the only limitation in their use for higher productivity is non-availability of a steady source water. Thus their benefit is conditional on the availability of a water supply.

In addition, inputs are valued at shadow prices which are supposed to reflect the marginal social value of using the relevant goods or factors. Hence, when incremental benefits are arrived at as net of inputs at shadow prices, the resultant profit can be attributed solely to the conditions that make possible a steady source of water supply.

The gross benefits arising out of providing electricity are computed in stages as follows:

1. Revenue to the electricity board/government from sale of electrical energy to consumers.

2. Value-added in border prices on additional agricultural land industrial output arising out of rural electrification.

3. Income distributional benefits which include the benefits arising out of additional employment.

The present value of the time profile of benefits at the social discount rate is compared with the discounted capital and operating cost streams to obtain the present value of net benefit. This study does not include the indirect benefits arising out of electricity use in households. The only benefit assumed is the higher revenue realizable from domestic consumers for lighting as against consumers using it to run pumpsets.

Villages with different socioeconomic and cultural backgrounds were carefully selected to find out the sensitivity of social profit to varying complementary inputs. The analysis of the results can lead one to broadly outline the policies/strategies required to maximize social benefits arising out of rural electrification.

Questionnaire Design

For the purpose of computing the social costs and benefits of rural electrification, information has been collected at the household and village levels. The questionnaire has been designed to elicit information on existing income distribution, the response of villages to electrification and installation of pumpsets, and increases in agricultural production due to the availability of electrical energy.

Sample Selection

Three states have been chosen: Punjab, Maharashtra, and Andhra Pradesh, in northern, western, and southern India, respectively.

Where possible, the villages covered in the 1966 study by Fliegel Roy, Sen and Kivlin (1967) were included. Sample selection is broadly based on two criteria: (1) category of rural electrification, and (2) socioeconomic and cultural background of villages.

Care has been taken to include various categories of schemes such as:

1. Ordinary-advanced areas
2. Ordinary-backward areas
3. Minimum needs program-tribal area
4. Special agricultural program

The survey of villages is spread over three states with differing foci.

Punjab:	Agriculturally and industrially advanced
Andhra Pradesh	Predominantly agricultural
Maharashtra	Agriculturally and industrially in the intermediate stage

The three states represent three distinct cropping patterns and the different agroclimate regions of the country.

Within each state, areas with varying economic and social backgrounds were identified. For example, in Andhra Pradesh an attempt has been made to choose an agriculturally advanced area, a drought-prone area, and a

backward tribal area. The main objective of such a selection is to examine the sensitivity of the social rate of return to varying complementary inputs. By studying the social yield obtained on rural electrification investment in different villages, one can broadly outline the influence of complementary inputs on maximizing social benefits.

Project Specific Shadow Prices

Any project which calls for the use of certain resource inputs to produce specific output affects the demand/supply position. If at the margin foreign trade is affected, then the appropriate shadow price for the input/output is Free on Board (FOB)/Customs Insurance and Freight (CIF) values, depending on whether the commodity is exported or imported. The appropriate price for the input is the social cost of production. If on the other hand at the margin the domestic consumption is affected, then the appropriate shadow price is the benefit foregone. For instance, while tradeables are valued at border prices, non-tradeables without supply constraints are valued at social cost of production and non-tradeables with supply constraints are valued at benefits foregone in efficiency prices. Labor is valued at the shadow wage rate. The computation of shadow wage rate has been discussed in detail in appendix B.

Computation of Reference Social Cost and Generation

Role of the Project Appraisal Division: Implication in Derivation of Social Prices

The current thinking in the Project Appraisal Division (PAD) is not to attempt to question the plan targets but to present economic rates of return for projects in the plan to the planner so that the projects may be reappraised in the light of the economic rates of return. In view of the limited role envisaged for the PAD, the consequent limitation on use of shadow price for inputs calls for treatment of potentially tradeable items as non-tradeable if the government discourages the import of items which are indigenously made at a significant cost.

Adjustment to Capital Cost

Ramagundam Super Thermal Power Project (RSTP), one of the super thermal stations for which firmed up capital costs in 1979/80 prices[3] were available, has been chosen to derive marginal cost of generation.

Care has been taken to remove the taxes and duties component in the capital cost. Foreign exchange values have been taken at a premium of 25 percent. Indirect FE flows have been identified and a premium has been applied. As per the document submitted by Ramagundam Super Thermal Project to the World Bank, the capital cost of the project is Rs. 6,253.90 million. The adjusted capital cost works out to Rs. 5,909.63 million, as indicated below:

Capital cost:		Rs. 6,253.90 million
Foreign exchange including indirect FE flows[4]	Rs. 808.00 million	
Premium on foreign exchange		Rs. 202.00 million
Customs duty		Rs. -323.00 million
Taxes		Rs. -134.07 million
Unskilled labor component	Rs. 222.15 million	
Social profit out of unskilled labor		Rs. -89.00 million
Adjusted capital cost		Rs. 5,909.83 million

The Ramagundam unit plans to install three 200 MW units and one 500 MW unit. The plant life is assumed to be twenty-five years of operation and the possible generation of energy units has been arrived at after deduction of auxiliary units consumption. The discounted capital cost to the base year at 12 percent discount rate is Rs. 3,163.73 million. The energy units discounted to base year works out to Rs. 16,651.97 million. The capital recovery per kWh at 12 percent works out to 19 paise per kWh.

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3. The 1979/80 prices mean price levels that existed in fiscal year April 1979 to March 1980. Price indices indicated in the report typically reflect the fiscal year price level.

4. Indirect FE flows is incurred on account of installation of hydrogen generation unit (the unit is supplied against rupee currency by RSTP while the supplied imports the equipment).

Table 4-2. Capital Cost Phasing and Energy Generation
(Capital phasing in Rs. million; energy units in million kWh)

Year of construction	Capital cost	Generated energy units
1	47.5	
2	342.57	
3	351.60	
4	760.00	
5	1,338.08	
6	1,200.61	76
7	600.97	879
8	583.59	1,911
9	512.05	2,984
10	172.66	3,681
11		4,572
12		5,590
13		5,590
--	--	--
--	--	--
--	--	--
29		5,590
30		4,754
31		3,557
32		2,547

Source: Ramagundam Super Thermal Power Project (RSTP), report to the World Bank.

Adjustment to Operating Cost

The boiler coal used by thermal stations has been treated as a non-tradeable good without supply constraints, since more than adequate proven reserves of boiler coal are available for extraction. The approaches followed to derive the shadow price of boiler coal fall in two broad categories:

1. Determination of price that will yield 12 percent return on capital employed by examining new investments in coal mining, particularly mining projects connected to proposed super thermal projects. The approach yields a social cost for boiler coal of Rs. 42-70/ton in 1977/78 prices for projects linked up to the Singrauli Super Thermal Project, as indicated below:

Jayant Open Cast Mine	Rs. 46/ton
Kusmunda	Rs. 42/ton
Dingapur	Rs. 70/ton
New Majari	Rs. 64/ton

Since all super thermal stations are located at the coal pithead, prices need not be adjusted for transportation costs to plant site.

2. In the second approach, the cost of mining coal per ton was arrived at by determining the regression equation for industry as a whole. The cost per ton of coal surried by open cast techniques is computed from the following relationships estimated from data on the coal industry:

Cost per ton (in 1977/78 prices) = 24.78 + 29.17 (strip ratio)

Since the average strip ratio is two, the cost per ton in 1977/78 prices works out to Rs. 83/ton.

Since the coal prices obtained by both approaches are in 1977/78 prices, they have been updated to 1979/80 price levels using the wholesale price index for all commodities. The updated prices are as follows:

Jayant Open Cast Mine	Rs. 57/ton
Kusumunda	Rs. 52/ton
Dingapur	Rs. 87/ton
New Majari	Rs. 79/ton
Based on regression study	Rs. 110/ton
Average	Rs. 77/ton

The average marginal cost of Rs. 77/ton has been used in the computations. Coal consumption (of calorific value 4,300 K Cals/kg) per kWh works out to Rs. 0.542 for a weighted rate of 2,030 K Cals/kWh and for a boiler efficiency of 87 percent. The coal cost per kWh works out to 4.17 paise. Labor and wages, operation and maintenance cost is assumed to be 2.25 percent of capital cost (Rs. 111.3/year) and works out to 2.2 paise/kWh. The assumption is based on the envisaged operational efficiency as spelled out in the project report and the projected expenditure on oil, lubricants, water, wages and salaries, and repairs.

The reference social cost of generation thus works out to:

Capital recovery to yield 12% return	19.00 paise/kWh
Coal cost	4.17 paise/kWh
Labor wages, operations, maintenance and salaries	2.20 paise/kWh
	25.37 paise/kWh

Cost of Transmission

The marginal cost of transmission is arrived at in a similar manner by examining projects belonging to the cost minimization set. The two projects for which firmed-up capital costs in 1979/80 prices are available are the investment proposals on transmission facilities in the north (Singrauli Super Thermal Project) and south (Ramagundam Super Thermal Project). The projected capital cost and operating cost streams of a typical project are as shown in table 4-3.

Table 4-3. Transmission Cost

Year of construction	Investment expenses excluding interest during construction in 1979/80 price levels	Operation & maintenance expenses	Purchased energy in 1,000 kWh	Transmitted energy less 2.5% (1,000 kW)
1	12.80	--	--	--
2	74.60	--	--	--
3	111.40	--	--	--
4	154.90	3.54	75	73
5	263.30	6.17	881	859
6	527.60	11.45	2,290	2,233
7	399.40	15.44	3,820	3,725
8	82.30	16.26	5,533	5,492
9	--	--	7,659	7,468
10	--	--	8,907	8,687
11	--	--	9,669	9,427
12	--	--	9,972	9,723
13	--	--	100,010	9,760
--	--	--	--	--
--	--	--	--	--
--	--	--	--	--
38	--	--	100,010	9,760

Source: Ramagundum Super Thermal Power Project, report to the World Bank; and Singrauli Super Thermal Project.

The transmission cost works out to 3.0 paise/kWh at a 12 percent social discount rate. For cost at tranmission point, 1 paise is added for energy loss to equal 4 paise/kWh.

Cost of Subtransmission

Marginal cost of subtransmission is again estimated in a similar manner by considering a project belonging to the cost minimization set. At 1979/80 price levels, the cost of 33/11 kilovolt (kV) substations are as follows:

		Rs. 100,000
33/11 kV	1 X 1.6 MVA	7.16
33/11 kV	1 X 3.15 MVA	8.93
33/11 kV	2 X 3.15 MVA	14.84
33/11 kV	1 X 5 MVA	10.07
33/11 kV	2 X 5 MVA	20.47

As the demand for power in rural areas is easily met by 33/11 kV 1 X 5 MVA substations this can be considered as a project belonging to the cost minimization set.

Using the relationship that 100 kVA is equivalent to 150 HP, we have 1 MVA equivalent to 1,500 HP or 1,119 kW. If the initial investment in step-down transformer is Rs. 3.007 million, then the capital recovery per kWh stepped down can be calculated. Capital cost per kilowatt is

$$\text{Rs.}\ \frac{10.07 \times 10^5}{1,119}$$

Assuming that a step-down transformer works around the clock, and the useful life cannot be expected to be beyond twenty years, the discounted kWh energy units stepped down over 20 years of useful life is 64,536.

Thus, the marginal cost per kWh stepped down is

$$\frac{10.07 \times 10^5}{1,119 \times 64,536} \times 100 \text{ paise} = 1.39 \text{ paise}$$

Even after assuming a nominal loss during step-down operations the cost per kWh for a step-down transformer cannot be expected to exceed 2 paise/kWh. Thus the marginal cost of electrical energy up to subtransmission, including the cost of generation, transmission at extra high tension voltage, and stepping down with a step-down transformer is

25.37 + 4 + 1.39 = 30.76 (approximately 31 paise per kWh)

The cost of energy lost in distribution has to be added to this cost in order to arrive at the cost of energy reaching the distributional centers. Since the energy lost in the distribution network averages out to around 18 percent, the cost of electrical energy made available at the distribution center is

$$\frac{31}{1 - 0.18} \text{ paise} = 38 \text{ paise/kWh}$$

Cost of Distributional or Capital Investments for Rural Electrification

The marginal cost of distributing electrical energy is location specific. That is, the marginal cost is dependent on consumer density, number of agricultural industrial connections provided, etc. Investment in distributing electricity to rural areas mainly comprises the capital costs associated with distribution transformers, HT and LT lines.

To sum up, the operating and capital cost flow streams are:

1. capital outflows for the cost of constructing the distribution network;
2. cost of operating and maintaining the network; and
3. cost of energy, excluding the capital recovery on account of distribution network and the operating and maintenance cost of distribution network, but including an allowance for loss of energy in the distribution network.

The cash inflow is the revenue realized from sale of electrical energy units.

Financial Net Present Value at Village Level

Based on the distribution network envisaged for every village a financial net present value (NPV) has been worked out. The financial NPV is the difference between cash inflows and cash outflows. If the revenue from consumers exceeds the present value of capital and operating cost streams of installing and maintaining a distribution network, then financial NPV is positive, meaning that providing electricity to rural areas is a financially viable proposition.

Preliminary Economic NPV

Preliminary economic NPV is arrived at after an adjustment for additional agricultural output made possible by rural electrification. That is, value-added in border prices on additional agricultural production over traditional dry farming is added to the financial NPV to obtain preliminary economic NPV. The 'value added' is computed after an adjustment for the premium on foreign exchange. As already pointed out in the earlier section, value-added in additional agricultural production is arrived at as follows:

$$(Q_2 \times P - Q_2 \times C_2) - (Q_1 \times P - Q_1 \times C_1)$$

where

Q_2 = current output

Q_1 = previous output

P = border price

C_2 = border price of fertilizer used per ton of output plus border price of pesticide used per ton of output plus shadow wage rate per ton of output

C_1 = social cost of using manure per ton of output plus shadow wage rate per ton of output

The border price of food grains used is the CIF value of output as the alternative to production is increased imports. The world prices of food grains can be described by two distributions--one normal with a $150/ton as

mean with a standard deviation of $30/ton. The other is a skewed distribution derived on the basis of the kinked demand function using a lower elasticity when world grain supplies are scarce and a higher elasticity when world grain supplies are abundant. The expected price in this case in $160/ton and the probabilities of high prices are much larger than with normal distributions. Since the government is a regular importer of fertilizer and pesticides these are valued at CIF values. The 'value-added' arrived at is after an adjustment for the premium on foreign exchange.

Adjustment for Impact on Savings

The additional income gained or lost by individual groups within the society is assumed to be equal to the distortion between shadow and market payments to each input or output in the case of physical resources or equal to the distortion between price paid and value received in the case of financial transactions. The groups considered for analysis in this study are:

- project
- government
- consumers
- land owners
- unskilled labor

In order to determine the savings impact one has to determine the amount of income gained or lost because of the project by different income groups. This study assumes the difference between preliminary economic NPV and financial NPV as the income being redistributed and further assumes that at 0 percent the net gain or loss between groups is zero.

The major steps involved are: (1) evaluation of the net impact of these gains/losses on savings given the marginal propensity to save of each groups, and (2) evaluation of additional savings at a premium by considering its impact on income distribution (guide: p. 64).

Although the adjustment factor for project and government is the same (P-investment - 1) these are considered as separate income groups to facilitate tracing of income flows. The adjustment factor is calculated

based on the assumption that all public sector profits are saved, unskilled workers save nothing, and the marginal propensity to save for consumers and land owners is 0.18.[5]

Income Distributional Impact

Income above reference level is less valuable while income below the reference value is more valuable than the income to the government. The decline or increase in value is obtained by the weights as shown under:

$$\left(\frac{\text{Reference group income}}{\text{Income level of group being studied}} \right)^{e}$$

where 'e' is the elasticity of marginal utility to increased consumption.

The reference income level in the study is the poverty line. The reference levels state-wide are as follows:

Maharashtra	-	Rs. 672/year
Punjab	-	Rs. 687/year
Andhra Pradesh	-	Rs. 582/year

The poverty line has been updated to 1979 price levels by the use of the consumer price index for agricultural labor as published by the labor bureau. In a number of places it is assumed that the major impact of rural electrification on minor irrigation will be the additional employment of unskilled labor for a further period of two months. Care has been taken to deflate the income of unskilled labor by the number of earners per household:average household size (see table 4-4 for data used to derive this index).

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5. Partha DasGupta (1978) uses the economy-wide savings rate of 18 percent in his exercise on the UNIDO guidelines for project evaluation.

Table 4-4. Data to Derive Index

	Average household size	Number of earners/household
Andhra Pradesh	4	2.25
Maharashtra	4.43	2.23
Punjab	5.50	1.73

No weight has been computed for the landowners class as the weight is bound to be very negligible in view of high elasticity of marginal utility to increased consumption and the high income level of that group.

Chapter 5

RESULTS, SUMMARY AND CONCLUSIONS

This social cost-benefit (SCB) analysis examines the costs of rural electrification and benefits for thirty villages in Andhra Pradesh, Maharashtra, and Punjab. The village rather than the utility has been chosen as the unit of analysis to determine the sensitivity of social profit to village location and demographic characteristics. In appendix C, detailed computations are shown for the village of Kampalapadu. The results for all thirty villages are summarized here in tables 5-1 and 5-2. Table 5-1 presents for each village the financial NPV, the economic NPV, and the economic NPV adjusted for the savings and income distribution impact. The differing characteristics of the villages used for sensitivity analysis are presented in table 5-2.

Table 5-1. Results By village

Village	Financial NPV (Rs.)	Preliminary economic NPV (Rs.)	Preliminary economic NPV adjusted for savings impact (Rs.)	Preliminary economic NPV adjusted for income distribution impact (Rs.)	Nature of benefit
ANDHRA PRADESH					
1. Kambalapadu	-122,409	- 113,620	- 142,551	- 267,418	SICP, groundnut to rice
2. Gosanipalli	- 54,965	- 17,551	- 43,210	- 157,265	SICP, groundnut to rice
3. Tallagokulapadu	-146,281	- 71,478	- 128,436	- 389,287	SICP, groundnut to rice
4. Krishnagiri	-195,312	- 45,678	- 143,165	- 589,880	SICP, groundnut to rice
5. Garla Dine	-339,136	+ 167,216	- 95,159	-1,298,125	SICP, groundnut to rice
6. Chittyala	- 81,650	- 6,847	- 52,239	- 254,922	SICP, groundnut to rice
7. Kalagampadi	- 96,858	- 96,858	- 117,199	- 204,371	DOM CON
8. Korukallu	-120,604	- 120,604	- 145,931	- 254,475	DOM CON
9. Garikapadu	-277,351	- 277,351	- 335,594	- 585,210	DOM CON
10. Mogalu	-122,421	- 122,421	- 148,130	- 258,309	DON CON
11. Navarasapuram	-116,558	- 57,263	- 72,983	- 133,600	ADD OUTPUT RICE
12. Yenuguvani Lanka	-194,850	- 135,555	- 167,728	- 340,435	ADD OUTPUT RICE
13. Arlitaraf	-155,273	- 155,273	- 187,880	- 327,626	DOM CON
14. Beempur	-159,618	- 159,618	- 193,138	- 336,794	DOM CON
15. Lachampur	-141,415	- 141,415	- 171,112	- 298,386	DOM CON
16. Sangdi	-187,006	- 157,006	- 226,277	- 394,582	DOM CON
17. Dhanora	-199,778	+ 239,976	+ 272,971	+ 426,329	ADD OUTPUT COTTON
18. Lingi	-155,715	- 53,106	- 68,318	- 124,526	ADD OUTPUT COTTON
MAHARASHTRA					
19. Chatnandru	-155,434	- 155,434	- 188,075	- 327,966	DOM CON
20. Meni	-276,279	- 276,279	- 334,297	- 582,948	DOM CON
21. Dasak	-345,414	- 219,210	- 283,870	- 601,261	ADD OUTPUT WHEAT
22. Manegaon	- 20,791	- 20,791	- 25,157	- 43,869	DOM CON INTN
23. Deothana	-107,398	- 94,878	- 116,544	- 206,869	ADD OUTPUT WHEAT
24. Sarwargaongore	-127,853	- 124,532	- 151,173	- 264,591	ADD OUTPUT WHEAT
25. Bhatambla	- 57,674	- 47,711	- 59,201	- 106,168	ADD OUTPUT WHEAT
26. Jawali	-208,797	- 172,265	- 213,833	- 379,024	ADD OUTPUT WHEAT
PUNJAB					
27. Sherpur	-796,772	+2,402,615	+2,423,830	+2,716,630	ADD OUTPUT WHEAT
28. Jessowal	-147,577	+ 653,024	+ 669,722	+ 792,347	ADD OUTPUT WHEAT
29. Khirzabad	+ 65,905	+ 214,854	+ 237,666	+ 344,405	ADD OUTPUT RICE/WHEAT
30. Mainpur	- 22,274	+ 70,819	+ 71,686	+ 81,342	ADD OUTPUT RICE/WHEAT

NOTE: 1. SICP refers to Switch in Cropping Pattern type of benefit.
2. DON CON refers to the case where rural electrification's prime purpose is for domestic lighting.
3. ADD OUTPUT refers to additional output of same crop made possible due to installation of a pumpset.

SOURCE: Present study.

Table 5-2. Basic Data for Analysis

Village	High tension lines (km)	Low tension lines (km)	Distribution transformers Type	Distribution transformers No.	Domestic connections No.	Agricultural connections No.	Industrial connections No.	Commercial connections No.	Acres affected	Type of benefit
ANDHRA PRADESH										
1. Kambalapadu	2.80	2.75	50 KVA	1	19	1	2	--	3	SICP-Groundnut to rice
2. Gosanipalli	--	2.50	--	--	9	5	1	--	13	SICP-Groundnut to rice
3. Tallagokulapadu	2.06	4.05	50 KVA	1	12	10	1	--	26	SICP-Groundnut to rice
4. Krishnagiri	6.25	2.72	63 KVA	1	18	4	1	1	52*	SICP-Groundnut to rice
5. Garla Dine	5.00	10.00	63 KVA	1	17	22	1	2	176	SICP-Groundnut to rice
6. Chittyala	2.20	1.33	25 KVA	1	7	1	--	1	26**	SICP-Groundnut to rice
7. Kalagampadi	2.80	1.47	25 KVA	1	41	--	1	--	--	DOM CON
8. Korukallu	4.30	2.60	25 KVA	1	73	--	1	2	--	DOM CON
9. Garikapadu	9.99	4.02	25 KVA 63 KVA	1	110	--	2	7	--	DOM CON
10. Mogalu	1.53	4.88	63 KVA	1	138	--	3	12	--	DOM CON
11. Navaraspuram	2.80	2.50	25 KVA	1	28	1 (10 HP)	--	1	20	ADD OUTPUT (rice)
12. Yenuguvani Lanka	1.66	7.81	25 KVA	1	100	1 (10 HP)	--	3	20	ADD OUTPUT (rice)
13. Arlitaraf	3.50	3.60	100 KVA	1	9	--	3	--	--	DOM CON
14. Beempur	5.58	1.90	63 KVA	1	10	--	2	2	--	COM CON
15. Lachampur	3.96	2.50	63 KVA	1	14	--	1	--	--	DON CON
16. Sangli	5.42	3.50	25 KVA	1	28	--	--	--	--	DOM CON
17. Dhanora	4.50	4.50	100 KVA	1	12	4	1	--	30	ADD OUTPUT (cotton)
18. Lingi	5.10	2.00	63 KVA	1	5	1	1	--	7	ADD OUTPUT (cotton)

Table 5-2. (Cont.)

Village	High tension lines (km)	Low tension lines (km)	Distribution transformers Type	Distribution transformers No.	Domestic connections No.	Agricultural connections No.	Industrial connections No.	Commercial connections No.	Acres affected	Type of benefit
MAHARASHTRA										
19. Chatnandu	3.2-	3.60	50 KVA	1	84	--	4	10	--	DOM CON
20. Meni	5.92	6.55	25 KVA	1	100	--	3	15	--	DOM CON
21. Dasak	10.80	2.00	50 KVA 100 KVA	2	132	47	2	4	190	ADD OUTPUT (wheat)
22. Manegaon	--	1.00	--	--	28	--	--	--	--	DOM CON
23. Deothana	3.00	1.48	25 KVA	1	32	4	2	--	10	ADD OUTPUT (wheat)
24. Sarwargaongore	2.50	3.40	25 KVA	1	17	1	1	--	3	ADD OUTPUT (wheat)
25. Bhatambia	1.40	0.63	63 KVA	1	--	3	--	--	15	ADD OUTPUT (wheat)
26. Jawali	5.18	3.00	25	1	29	18	2	--	55	ADD OUtPUT (wheat)
PUNJAB										
27. Sherpur	8.28	34.4	100 KVA	1	137	170	17	1	850	ADD OUTPUT (rice/wheat)
28. Jessowal	2.70	6.0	100 KVA	1	66	43	3	1	210	ADD OUTPUT (rice/wheat)
29. Khirzabad	1.8	2.0	--	--	200	8	4	13	40	ADD OUTPUT (rice/wheat)
30. Mainpur	1.7	1.6	63 KVA	1	80	5	3	6	25	ADD OUTPUT (rice/wheat)

*Equivalent acres (lands are irrigated twice).

**Acres affected seem to be not proportional to agricultrual connections provided.

Financial Viability of Rural Electrification Schemes

A financial analysis of rural electrification schemes reveals that the capital and operating outlays for providing electricity to rural areas exceed the revenue from consumers at the test discount rate of 12 percent.

A further examination of results reveals that villages electrified under 'intensification'[6] schemes incur minimum loss. For instance, the villages of Gosanipalli and Manegeon incur a financial loss of only Rs. 54,965 and Rs. 20,791, respectively. The loss decreases as the number of domestic connections provided increases in the case of villages electrified under intensification schemes. Gosanipalli village provided electricity to nine households. An analysis of the results reveals that to break even financially, at least fifty households should be provided connections from intensification schemes.

Villages not far from the central grid can also break even if the distribution network is optimally laid. For instance, if one examines the villages which are located near the central grid, interesting results appear.

Villages	HT Lines (km)	Financial NPV	Number of domestic connections
Khirzabad	1.80	+ 65,905	200
Mainpur	1.70	- 22,274	80
Yenuguvani Lanka	1.66	- 194,850	100
Mogalu	1.53	- 122,421	138

The villages of Khirzabad and Mainpur have a high density of customers. The resulting distribution network is optimum yielding minimum loss or even marginal positive NPV (as in the case of Khirzabad). The villages of Yenuguvani Lanka and Mogalu suffered a much greater financial loss. It is not clear whether this was due to a low density of consumers or to a sub-optimum layout of distribution network.

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6. Villages electrified under intensification schemes do not call for laying of HT lines or distribution of transformers due to already spare capacity availability.

The two points indicate that the choice before the domestic government is limited to the following:

1. Increase of tariff rates to make REP financially viable. This could reduce the demand for electrical energy and its impact can be gauged only after determination of price elasticity of demand.

2. Examination c.' schemes that will make use of electricity popular so that closer cluster of customers is possible.

3. Optimal design of distribution network and priority to 'intensification' schemes.

Economic Viabiilty of Rural Electrification Schemes

Switch in Cropping Patterns

An examination of villages that experience a switch in cropping patterns due to electrification (see table 5-3) reveals that for preliminary economic NPV to turn positive around 100 acres of land must be affected. The preliminary economic NPV adjusted for savings and income distribution impact is negative because the land owners gain much more than the government due to the switch over. The market price of groundnut is highly depressed and it pays (financially) for the land owners to switch over. The difference between market prices and border prices for groundnut can be explained by the low efficiency of domestic oil expellers who are not able to pay the fair price to groundnut growers. However, the conclusions reached regarding groundnut are tentative and need to be researched in detail.

Table 5-3. Switch in Cropping Pattern: Select Villages

Village	Financial NPV (in rupees)	Preliminary economic NPV (in rupees)	Preliminary economic NPV adjusted for savings & income distribution impact (in rupees)	Acres affected
Krishnagiri	-195,312	- 45,678	- 586,880	52
Garla Dine	-339,136	+167,216	-1,298,125	176
Chittyala	- 81,650	- 6,847	- 254,922	26

Additional Output

An analysis of the results for villages experiencing additional output of rice or wheat indicates that preliminary economic NPV can turn positive even if affected area is around fifty acres (see table 5-4). If acres affected is around 200 or more, the social benefit reaped is very significant. The other salient points that emerge from the analysis are:

1. The income distribution benefits are not significant as financial prices are not significantly different from border prices.

2. Acres affected are not the only factor determining financial and economic NPV. Higher productivity through the use of pumpsets is also a significant factor. The case of villages in Maharashtra not showing significant social profit even when acres affected are of the same order as those villages in Punjab can be explained by higher productivity achieved in Punjab farms.

3. Prioritizing areas for rural electrification could entail choosing areas where at least fifty to sixty acres would be affected by rural electrification.

Table 5-4. Additional Output of Rice/Wheat: Select Villages

Village	Financial NPV (in rupees)	Preliminary economic NPV (in rupees)	Preliminary economic NPV adjusted for savings & income distribution impact (in rupees)	Acres affected
Navavasapuram	-116,558	- 57,263	- 133,600	20
Yenuguvani Lanka	-194,850	- 135,555	- 340,435	20
Deothana	-107,398	- 94,778	- 206,869	10
Sarwargaongore	-127,853	- 124,532	- 264,591	3
Bhatambia	- 57,674	- 47,711	- 106,618	15
Sherpur	-796,772	+2,402,615	+2,716,630	850
Jessowal	-147,577	+ 653,024	+ 792,347	210

Risk Reduction

An analysis of the results in table 5-5 reveals that in cotton-growing areas it is socially profitable to provide rural areas with electricity even if only ten acres are to be affected. The farmers felt that the need

for a pumpset is acutely felt in regions growing cotton when the monsoon fails. During critical periods, such failure can be a total financial ruin to the farmers.

Table 5-5. Reduction in Risk of Crop Failure and Increase in Yield of Cotton Crop

Village	Financial NPV (in rupees)	Preliminary economic NPV (in rupees)	Preliminary economic NPV adjusted for savings & income distribution impact (in rupees)	Acres affected
Dhanora	-199,778	+239,976	+426,329	30
Lingi	-155,715	- 53,106	-124,526	7

Social Viability of Rural Electrification Schemes

Acres to be Affected for Social Profit to Break Even

An analysis of the results indicates that the acres to be brought under pumpset irrigation for social profit to break even varies with the type of benefits. It is as low as ten acres for cotton crop where the nature of benefit is reduction in risk and increase in agricultural production.

It will be recalled that the preliminary economic NPV becomes positive if there is a switch in cropping pattern from groundnut to rice if the acres affected lie in the range of 100. However, the net income distribution benefits are always negative as land owners gain more than the government.

The acres to be affected for social profit to break even are fifty to sixty if the nature of benefit is additional production of rice/wheat. There are no significant income distributional benefits as the distortion between market and border prices is minimum.

Regions under Extensive Canal Irrigation

No significant agricultural connections are sought in regions where there is extensive canal irrigation. For instance, provision of electricity to rural areas in affluent regions of West Godavari has not resulted in any significant increase in agricultural production. Similarly, social profit is not significant in regions endowed with good monsoon and provided with electricity, as it is used for only domestic lighting.

Regional Factors Affecting Social Profitability

1. The economic and social benefits are very significant in the case of Punjab, an agriculturally and industrially advanced state, as compared to Maharashtra (which is agriculturally and industrially in the intermediate stage) even when the nature of benefit and acres affected are of same order.

Village	Agricultural connections sought	Nature of benefit	Economic NPV after adjustment of savings & income distribution impact
Region: Punjab			
Khirzabad	8	Add prod rice/wheat	Rs. +344,405
Mainpur	5	Add prod rice/wheat	Rs. + 81,342
Region: Maharashtra			
Deothana	4	Add prod rice/wheat	Rs. -206,869
Bhatambia	3	Add prod rice/wheat	Rs. -106,168

2. Even in an advanced state such as Punjab there are significant differences in social profit between regions affected by the regional level of development.

Ordinary advance scheme

Village	Social profit
Sherpur	+2,716,630
Jessowal	+ 792,347

Ordinary backward scheme

Village	Social profit
Khirzabad	+ 344,405
Mainpur	+ 81,342

An analysis of the agriculturally advanced area, a drought-prone area, and a backward tribal area in Andhra Pradesh yield interesting results.

The response of tribal area is below normal. Agricultural connections have not been sought from the bulk of the villages.

The response in the drought-prone area is comparatively better. The response can be easily improved if the risk associated with the failure of crops in the case of high-yielding varieties is minimized by the state.

The response in the advanced area is also poor as the area is extensively served by canal irrigation.

Conclusions and Policy Implications

This study critically analyzed the available methodologies for carrying out a social cost-benefit analysis of rural electrification schemes. The study derived the necessary shadow prices for evaluation. In order to measure marginal costs involved in rural electrification the study identified a cost minimization set. It also identified the cost of distributing electricity to rural areas as location specific. Marginal cost up to the subtransmission stage was derived as an average cost from the cost minimization set. The study classified the major agricultural benefits in three broad categories and using project specific--and national--shadow prices proceeded to measure the net social benefit.

In the study, the village rather than the utility was taken as the unit of analysis. The village was chosen as unit of analysis to determine the sensitivity of social profit to village location and demographic characteristics.

The study assumed that rural electrification projects fall outside the basic category of projects in which postponement is not possible. In the case of resource constraints the state can prioritize areas for rural

electrification. The study identified the variables affecting social profitability as:

- Extent of other irrigation possible such as canal irrigation.
- The type of benefit that can be expected.
- The expected response from customers for agricultural connections.
- Social conditions of the region such as advanced, backward, tribal, drought-prone areas, etc.
- Alternative cost-effective centralized distribution schemes available.
- Prevailing schemes for credit and crop insurance schemes, etc.

Social profitability was higher in advanced regions compared to backward regions. This could be a reason for giving priority to advanced regions for rural electrification. Similarly, in drought-prone areas, the response can be more favorable if cheap credit and crop insurance schemes are carried out. In tribal areas electrification could be postponed if resource availability is a constraint.

Prioritizing areas depending on nature and type of benefit could also be effected. For instance, higher priority, for rural electrification could be accorded to areas growing cotton in view of reduction of risk of crop failure. Similarly, break-even areas for varying types of benefits gives the state effective operational guidelines for prioritizing areas for rural electrification.

Appendix A

Table A-1. Summary of Ratios of Social to Market Wage Rates for Rural Labor, by States

	Rural		
	K1[a]	K2[b]	K3[c]
Andhra Pradesh	1.00	1.00	1.00
Maharashtra	0.76	0.74	0.76
Punjab	0.94	0.94	0.94

[a]K1 = Assuming no rural surplus.

[b]K2 = Assuming maximal estimates of rural surplus labor valid.

[c]K3 = On ´best´ estimates of rural surplus labor.

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Table A-2. Derivation of Social Wage Rate for Rural Male Labor, by States

	Andhra Pradesh	Maharashtra	Punjab
1. 1971 census percentage rate of labor force in agriculture	79.51	78.84	79.12
2. Percentage of male labor force unemployed	0.49	1.16	0.88
3. Average daily male wage rate 1970-71 rupees	2.22	2.28	4.97
4. Value of market price of agricultural output foregone--Estimate I	2.209	2.234	4.926
5. Market estimates of proportion of agricultural workers in surplus	2.83	2.03	1.31
6. Value at market price of output foregone--Estimate II	2.146	2.208	4.862
7. Best estimates of surplus labor force in agriculture	0.00	0.00	0.00
8. Value at market price of output foregone--Estimate III	2.208	2.254	4.926
9. Agricultural output conversion factors	1.04	0.77	0.94
10. Social value of output foregone--Estimate I	2.297	1.736	4.63
11. Social value of output foregone--Estimate II	2.232	1.700	4.57
12. Social value of output foregone--Estimate III	2.297	1.736	4.63
13. Rural consumption conversion factor	0.97	0.77	0.85
14. Marginal distribution weight for agricultural labor	0.981	1.17	0.971
15. Net social increase in consumption--Estimate I	0.0002	-0.0035	-0.0345
16. Net social increase in consumption--Estimate II	0.0013	-0.0095	.0853
17. Net social increase in consumption--Estimate III	0.0002	-0.0035	0.0345

Table A-2. (Cont.)

	Andhra Pradesh	Maharashtra	Punjab
18. Social wage rate, Estimate I	2.297	1.732	4.665
19. Social wage rate, Estimate II	2.233	1.691	4.656
20. Social wage rate, Estimate III	2.297	1.732	4.665
21. Ratio of social to market wage, Estimate I	1.035	0.760	0.939
22. Ratio of social to market wage, Estimate II	1.006	0.742	0.937
23. Ratio of social to market wage, Estimate III	1.035	0.760	0.939

Note: Since nominal wager rate (NWR) and social wage rate (SWR) are almost equal with L&M numeraire, no further adjustment of SWR for UNIDO numeraire has been carried out. See text for reasons.

Source: Government of India, Planning Commission, Technical Working Paper (1974).

Table A-3. Capital Cost Data for 33/11 KV 1 x 5 MVA Substation

Sr. no.	Particulars	Unit	Rate	Quantity	Amount (Rs.)
1.	33 KV insulator with earth blades	no	11,765	1	11,765
2.	33 KV isolator without earth blades	no	10,040	2	20,080
3.	33 KV lightning arrestors	set	5,272	2	10,544
4.	33 KV horn gap fuses	set	1,650	1	1,650
5.	33/11 KV 5MVA transformer with OLTQ	no	446,200	1	446,200
6.	11 KV switchgear complete with one incoming from outgoing panels with cable and cable boxes	LS	288,300	1	288,300
7.	11 KV lightning arrestors	set	540	1	2,160
8.	Station transformer (100 KVA) with distribution box	no	12,150	1	12,150
9.	30 V battery set with charges and AC/DC board	no	16,760	1	16,760
10.	Busbar material, clamps earthing, etc.	LS	42,950	1	42,950
11.	Structures and foundations including takeoff structures	LS	42,564	1	42,564
SUBTOTAL					895,123
12.	Contingencies - 3% of subtotal				26,853
13.	T & P - 1 1/2% of substotal				13,426
14.	Labor charges				46,365
15.	Transport				7,610
16.	Special T & P (transport vehicles) at 2%				17,902
GRAND TOTAL					Rs. 1,007,029

Table A-4. Capital Cost for Pole Mounted 63 KVA Distribution Transformer Substation, 11/0.433 KV, 64 KVA

Sr. no.	Description of materials	Unit	Quantity	Unit (Rs)	Amount
1.	63 KVA 11/0.433 distrubution transformer	no	1	6,535	6,535
2.	9 m long PSC pole 30 KG/m (60 lb/yd) rail pole	no	2	180/715	360/1430
3.	M.S. channel for top and transformer mounting crossarms 100 mm x 50 mm x 6 mm, 0.2 kg/m	kg	100	2.60	260
4.	M.S. channel 75 mm x 40 mm x 6 mm, 7.1 kg/m	kg	22	2.60	57
5.	M.S. angle 50 mm x 50 mm x 6 mm, 4.5 kg/m	kg	22	2.61	57
6.	M.S. flat 50 x 6 mm, 2.4 kg/m	kg	24	2.90	70
7.	Distribution box	kg	1	937	937
8.	Lightning arrestors, 11 KV	set	1	445	445
9.	11 KV D. O. fuse unit, set of 3	no	1	769	769
10.	Earthing sets (pipe/rod) HT	no	3	35	105
11.	Stay sets, HT	no	4	51.90	208
12.	Stay wire 7/10 SWG	kg	25	4.50	113
13.	G.I. wire 8 SWG	kg	4	4.6	18
14.	Barbed wire	kg	15	6.3	95
15.	Danger boards	no	2	3.95	8
16.	11 KV strain set complete with hardware	no	3	120	360
17.	11 KV pin insulators with pins	no	3	40	120
18.	LT PVC wire 4 core 50 mm^2	m	22	60	1,320
19.	LT PVC wire 3 1/2 core 70 mm^2	m	7.5	80	600
20.	Painting of hardware and support	--	LS	LS	25
21.	Concreting of poles & stays	cmt	2	150	300
22.	Sundries such as nut-bolts clamps, PVC sleeves, soldering	--	LS	LS	250
TOTAL				13,012/14,082	
Direct charges:	(a) contingencies-3% and T & P 1 1/2%				585/635
	(b) Labor charges as per schedule in text				580
	(c) Transport charges @ 4% of cost of materials				520/563
				14,697/15,360	

Approximately equal to (On 9m long PSC poles) Rs. 14,700/-
(On 9m long 30 kg/m rail poles (Rs. 15,300)

Table A-5. Capital Cost for Pole Mounted 25 KVA Distribution Transformer Substation

Sr. no.	Description of materials	Unit	Quantity	Rate per unit (Rs)	Amount (Rs)
1.	25 KVA 11/0.433 distrubution transformer	no	1	4,880	4,880
2.	9 m long PSC pole 30 KG/m (60 lb/yd) rail pole	no	2	180/715	360/1430
3.	M.S. channel for top and transformer mounting crossarms 100 mm x 50 mm x 6 mm, 0.2 kg/m	kg	100	2.60	260
4.	M.S. channel 75 mm x 40 mm x 6 mm, 7.1 kg/m	kg	22	2.60	57
5.	M.S. angle 50 mm x 50 mm x 6 mm, 4.5 kg/m	kg	22	2.61	57
6.	M.S. flat 50 x 6 mm, 2.4 kg/m	kg	24	2.90	70
7.	Distribution box	kg	1	634	634
8.	Lightning arrestors, 11 KV	set	1	445	445
9.	11 KV D.O. fuse unit, set for 3	no	1	769	769
10.	Earthing sets (pipe/rod) HT	no	3	35	105
11.	Stay sets, HT	no	4	51.90	208
12.	Stay wire 7/10 SWG	kg	25	4.5	113
13.	G.I. wire 8 SWG	kg	4	4.6	18
14.	Barbed wire	kg	15	6.3	95
15.	Danger boards	no	2	3.95	8
16.	11 KV strain set complete with hardware	no	3	120	360
17.	11 KV pin insulators with pins	no	3	40	120
18.	LT PVC wire 4 core 16 mm	m	30	18.21	546
19.	Painting of hardware and support	--	LS	LS	25
20.	Concreting of poles & stays	cmt	2	150	300
21.	Sundries such as nut-bolts clamps, PVC sleeves, soldering	--	LS	LS	250
TOTAL				9,680/10,750	
Direct charges:	(a) contingencies-3% and T & P 1 1/2%				435/485
	(b) Labor charges as per schedule in text				580
	(c) Transport charges @ 4% of cost of materials				387/480
				11,082/12,295	

Approximately equal to (On 9m long PSC poles) Rs. 11,100/-
(On 9m long 30 kg/m rail poles (Rs. 12,200)

Table A-6. Capital Cost for Pole Mounted 100 KVA Distribution Transformer Substation

Sr. no.	Description of materials	Unit	Quantity	Rate per unit (Rs)	Amount (Rs)
1.	100 KVA 11/0.433 distrubution transformer	no	1	7,560	7,560
2.	9 m long PSC pole 30 KG/m (60 lb/yd) rail pole	no	2	180/715	360/1430
3.	M.S. channel for top and transformer mounting crossarms 100 mm x 50 mm x 6 mm, 0.2 kg/m	kg	100	2.60	260
4.	M.S. channel 75 mm x 40 mm x 6 mm, 7.1 kg/m	kg	22	2.60	57
5.	M.S. angle 50 mm x 50 mm x 6 mm, 4.5 kg/m	kg	22	2.61	57
6.	M.S. flat 50 x 6 mm, 2.4 kg/m	kg	24	2.90	70
7.	Distribution box	kg	1	1,265	1,265
8.	Lightning arrestors, 11 KV	set	1	445	445
9.	11 KV D.O. fuse unit, set of 3	no	1	769	769
10.	Earthing sets (pipe/red) HT	no	3	35	105
11.	Stay sets, HT	no	4	51.90	208
12.	Stay wire 7/10 SWG	kg	25	4.50	113
13.	G.I. wire 8 SWG	kg	4	4.6	18
14.	Barbed wire	kg	15	6.3	95
15.	Danger boards	no	2	3.95	8
16.	11 KV strain set complete with hardware	no	3	120	360
17.	11 KV pin insulators with pins	no	3	40	120
18.	LT PVC wire 3 1/2 core 70 mm^2	m	22	80	1,760
19.	LT PVC wire 3 1/2 core 150 mm^2	m	7.5	108	810
20.	Painting of hardware and support	--	LS	LS	25
21.	Concreting of poles & stays	cmt	2	150	300
22.	Sundries such as nut-bolts clamps, PVC sleeves, soldering	--	LS	LS	250
TOTAL				15,315	16,085
Direct charges:	(a) contingencies-3% and T & P 1 1/2%				675/723
	(b) Labor charges as per schedule in text				580
	(c) Transport charges @ 4% of cost of materials				601/643
				16,871 /	18,031

Approximately equal to $\frac{\text{(On 9m long PSC poles) Rs. 17,100/-}}{\text{(On 9m long 30 kg/m rail poles (Rs. 18,200)}}$

Capital cost of LT lines/km assumed for the study - Rs. 22,700/-

Table A-7. Capital Cost for HT Lines: Wind Pressure 100 kg/m^2
11 KV spur line using 8 m RSJ poles and 13 m 30 kg/m 8 m pole
cut point per km ACSR

Sr. no.	Description	Unit	Quantity	Rate	Amount
1.	RSJ 175 mm x 85 mm x 8 m long 100 mm x 116 mm	no	14	429	6,006
2.	Rail pole (30 kg/m) 8 m	no	1	660	660
3.	S flat 50 mm x 10 mm	kg	50	2.9	145
4.	MS channel 75 mm x 60 mm x 6 mm	kg	170	2.6	442
5.	11 KV pin insulators with pins	set	45	40	1,800
6.	11 KV stream sets	set	6	120	720
7.	ACSR conductor 20 mm^2 7/2.59 mm	set	3.1	2,200	6,820
8.	Jointing sleeve for ACSR	no	3	5.15	15
9.	Stay sets HT	no	7	51.90	363
10.	Stay wire 7.10 SWG	kg	40	4.5	180
11.	Earthing coils	no	15	10	150
12.	Anti-clunching devices	no	4	5	20
13.	Danger board	no	4	3.95	16
14.	Binding wire	kg	1	28	28
15.	Binding tape	kg	1	21	21
16.	Back-filling of pope pits with bonlees	no	15	10	150
17.	Concreting of stays and base pads for support	cmt	7	150	1,050
18.	Black bituminous paint	ltr	6.5	3.39	22
19.	Red oxide paint	ltr	13	8.71	113
20.	Aluminum paint	ltr	4	10.95	44
21.	Sundries				170
SUBTOTAL					18,935
Contingencies - 3 % and T & P 1 1/2%					852
Labor charges					1,394
Transport charges @ 4% of cost of materials					758
TOTAL					21,939

Approximately Rs. 21,900/km for 100 kg/m^2 wind pressure

Appendix B

SHADOW PRICES FOR APPRAISING RURAL ELECTRIFICATION PROJECTS

In this appendix necessary national parameters for project evaluation are estimated.

Table B-1 lists the estimated parameters. Subsequent sections briefly describe the assumptions made in the derivation of these parameters.

The Shadow Price of Foreign Exchange

The UNIDO Guidelines for Project Evaluation (1972) uses a foreign exchange shadow price based on marginal social value as revealed by the consumers' willingness to pay for foreign exchange necessary to finance REP by foregoing the consumption of other goods. Algebraically, it can be put in the following manner (guide: p. 48):

$$SER = OER \left(\frac{(M + T_i) + (X + S_x)}{M + X} \right)$$

where:

SER = shadow exchange rate
OER = official exchange rate
M = CIF value of imports
X = F.O.B. value of export
T_i = import tax revenue
S_x = export subsidies

(Note: Quantitative restrictions will have to be considered in the form of tariff equivalents.)

Table B-1. Summary of National Parameters

Parameter	Probable value	Remarks
1. Shadow Exchange Rate (SER)	1.25	SER is 1.25 times the official exchange rate
2. Marginal Productivity of Capital (q)		
Estimate	0.20	Using ICOR for the economy as a whole
Estimate	0.12	Considering only the modern sector
3. Consumption Rate of Interest (i)	10-11%	11% assumed for the study to have a plausible P_{INV} value
4. Elasticity of Marginal Utility to Increased Consumption (e)	3	Obtained indirectly as a mutually consistent value of CRI, growth rate, etc.
5. Global Marginal Propensity to Save (MPS)	0.34 to 0.40	0.40 assumed for the study
6. Global Marginal Propensity to Consume (MPC)	0.60	Obtained at (1 - MPS)
7. The Overall Social Value of Investment in terms of Consumption (P inv)	1.32 to 2.56 for range of 'i' - 11-8%	1.32 has been assumed for the study
8. Shadow Wage Rate (SWR)	0.60	Equal weight has been given to agricultural workers' consumption and the consumption of the government
9. GINI Coefficient (GINI)	0.28	
10. Distribution of Consumption Parameter ( )	2.29	
11. Global Distribution Weight (d)	1.68	
12. Per Capita GDP in 1979/80	Rs. 1,484/year	
13. Critical Consumption Level		
Estimate	Rs. 1,374	Based on D
Estimate	Rs. 1,365 to Rs. 1,068/year	For P inv values of 1.29 to 2.56
Estimate	Rs. 647/year	Poverty level estimate (this has been used for the study)
14. Period to attain optimality in savings rate	50 years	
15. Accounting rate of interest	12%	

Other implicit assumptions made in the approach are as follows:

1. Domestic market prices for all trade goods are taken as a measure of social worth.

2. The divergence between social and market prices is accounted for by taxes and duties.

3. Income elasticity for commodities is unity.

4. Past average rates of taxes and duties are assumed to reflect trade policy over the useful life of the project.

5. The elasticities of import demand and export supply are assumed to be infinitely elastic.

Table B-2 presents data on imports and import duties levied in the recent past.

Table B-2. Value of Imports and Import Duties

	1974/75	1975/76	1976/77	1977/78	1978/79
Import Duties (in 10^7 Rs.)	1,237	1,315	1,456	1,646	2,041
Import (in 10^7 Rs.)	4,519	5,265	5,074	6,026	5,811
Duties as a percent of imports	27.4%	25.0%	28.7%	27.3%	35.1%

Note: Average ratio of duties as a percentage of imports is 29 percent.

Source: Statistics of Foreign Trade & Budget Papers Government of India (various issues).

An analysis of the data in table B-2 indicates that 'apparent' premium on foreign exchange (FE) is around 29 percent (if duties alone are considered for application for FE premium). Duties in table B-2 represent 'apparent' premium as the assumptions 1, 2, and 4 are likely to be violated as shown in table B-3 below.

Table B-3. Imports and Duties in Constant 1975 Prices

	1974/75	1975/76	1976/77	1977/78
Import duties (in 10^7 Rs.)	1,237	1,315	1,456	1,646
Price index from national accounts	162.5	154.5	165.2	170.7
Import duties (in 10^7 Rs. in 1974/75 price levels)	1,237	1,384	1,432	1,567
UN Unit value index for manufactured goods	180	217	220	236
Imports deflated to 1974/75 price levels	4,519	4,367	4,151	4,596
Import duties as a % of imports (in real terms)	27.4	31.7	34.5	34.1

Note: Average for four years is 32 percent.

Source: Government of India, National Income Statistics, various issues; Government of India, Statistics of Foreign Trade & Budget Papers, various issues.

An analysis of data in table B-3 reveals that average 'real' duties as a percentage of imports was around 32 percent and steadily increased over the 1974-1978 period.

Computation of subsidies as a percentage of FOB value exports was more difficult to obtain. Since the bulk of imports is oil, and exports are increasingly manufactured goods and machinery, the amount of subsidy involved can be measured by taking a sample of modern industrial units.

Subsidy rates for ten Industrial Credit and Investment Corporation of India (ICICI) exporting companies appear in table B-4.

Table B-4. Subsidy Rated for Units Promoted by the Industrial Credit and Investment Corporation of India

	Actual total subsidy (direct & indirect) % of FOB	Proportion of exports in 1979/80	Weighted subsidy
1. Light & commercial vehicles	28	0.090	2.52
2. Textile machinery	11.5	0.012	0.12
3. Electrical machinery	17	0.052	0.91
4. Casting and forgings	4	0.002	0.01
5. Steel tubes and pipes	15	0.032	0.48
6. Textiles	23	0.669	15.39
7. Chemicals	0	0.143	--
		1.000	19.44

Note: Average subsidy is 20.36 percent of FOB of exports.

Source: Prices for Planning (Heineman Educational Publications, 1980).

The premium on foreign exchange is obtained by applying the formula:

$$\frac{\text{Imports}}{(\text{Imports} + \text{Exports})} \times \text{Duties } (\%) + \frac{\text{Exports}}{(\text{Imports} + \text{Exports})} \times \text{Subsidies } (\%)$$

$$- \frac{\text{Exports}}{(\text{Imports} + \text{Exports})} \times \text{Export tax}$$

where:

Duties (%) = duties as a percentage of CIF value
Subsidies (%) = subsidies as a percentage of FOB value
Export tax = taxes levied on exports of traditional commodities.

From the data listed in tables B-2, B-3, and B-4, and observing that imports constitute 58 percent and exports 42 percent of imports and exports, we have the weighted premium ignoring export taxes as

$$0.58 \times 32 + 0.42 \times 20 = 27\%$$

After adjustment for export taxes, the foreign exchange premium works out to 23 percent. Thus the shadow price of foreign exchange is 1.25 times the official exchange rate.

Marginal Productivity of Capital, Social Value of Investment, and Shadow Wage Rate

Marginal productivity of capital is the annual increment of output (assumed constant) in the economy due to a unit of reinvestment. However, the marginal productivity of capital for an industrial project in the public sector whose investment comes from nonagricultural sectors such as manufaturing, transport, communication, mining, etc., is the annual increment of output in the nonagricultural sector. To determine the marginal productivity of capital, assuming that the investment is from the economy as a whole, the incremental capital output ratio (ICOR) has to be estimated.

Table B-5. Incremental Gross Capital Output Ratio for the Economy as a Whole

Plan	Period covered	Incremental gross capital output ratio
First Plan	1951/52-1955/56	3.2
Second Plan	1956/57-1960/61	4.1
Third Plan	1961/62-1965/66	5.4
Fourth Plan	1969/70-1973/74	3.7
Fifth Plan	1974/75-1978/79	3.9

Note: Average for the five plans is 4.5.

Source: Government of India, Sixth Five Year Plan, 1980-85 - Plan Document.

Thus the increment in output per unit of investment (Y) is 22 percent. The rate of net profit due to investment is arrived at by subcontracting the marginal product of labor per unit of investment from the incremental output per unit of investment. If in the modern sector 'l' jobs can be created per unit of investment and if 'W' is the industrial wage rate of unskilled labor (assumed as marginal the product of labor), then the net profit due to investment is obtained as

$$Y - Wl$$

The average wage of labor in the modern sector in 1979/80 prices is Rs. 11,500 per year. Investment in the public sector between 1974 and 1979 was Rs. 93.65 billion, while the growth of employment between 1975 and 1979 was about 200,000. Thus the investment per employment generated works out to Rs. 468,200 and the marginal product of labor per unit of investment works out to 0.02. The rate of net profit due to the investment, considering ICOR for the economy as a whole, works out to 0.20.

The value added at 1979/80 prices for 1980-1985 divided by the investment 1979/80 prices for 1980-1985 works out to 0.14. The rate of net profit due to investment in the modern sector works out to 0.14 - 0.02 = 0.12. The alternative estimate of marginal porductivity of capital works out to 0.12.

Table B-6. ICOR in the Modern Sector
(Gross investment by destination sector and increment in Gross Domestic Product at factor cost, 1980-1985)
(Rs. 10^7 in 1979/80 prices)

	Investment at market prices	Incremental GDP at factor cost	ICOR
Manufacturing	45,515	6,500	7.00
Construction	1,760	1,389	1.29
Railway and other transport	16,054	1,445	11.11
Communications	2,902	262	11.08
Mining and quarrying	6,575	1,040	6.32

Note: Average for the modern sector is 7.36.

Source: Government of India (1981).

Social Value of Investment in Terms of Consumption

It has already been shown that the net return due to a unit of investment is given by Y - Wl where Y represents the incremental output and Wl represents the wage payment paid out of the incremental output. Assuming that the labor for the industrial sector comes from the agricultural sector, let 'g' be the marginal product of labor in the agricultural sector and 'S' represent the global marginal propensity to save out of profits then it follows that (1-S)(Y - Wl) will be consumed. If P-investment (P-inv) represents the value of investment in terms of consumption, then the contribution of net profit to aggregate consumption is:

$$\text{P-inv} \times S(Y - Wl) + (1 - S)(Y - Wl)$$

If it is further assumed that unskilled laborers save nothing then their contribution to aggregate consumption is (W - h)l. Thus, if 'i' is the consumption rate of interest, we have

$$\text{P-inv} = \frac{\text{P-inv } S(Y - Wl) + (1 - S)(Y - Wl) + (W - g)l}{i}$$

Solving for P-inv, one obtains

$$\text{P-inv} = \frac{(1 - S)(Y - Wl) + (W - g)l}{i - (Y - Wl)}$$

<u>Estimation of Global Marginal Propensity to Save (MPS)</u>

Ignoring the terms of trade effect the MPS can be expressed as:

$$= \frac{GDS_{\text{in } 1977/78} - GDS_{\text{in } 1975/76}}{GDP_{\text{in } 1977/78} - GDP_{\text{in } 1975/76}} = \frac{5116}{15222} = +0.34$$

An alternative estimate of marginal propensity to save (Partha DasGupta, 1978) is obtained as the ratio of

$$\frac{\text{Increment in government investment}}{\text{Increment in government expenditure}}$$

Estimation of Consumption Rate of Interest (CRI)

The consumption rate of interest is obtained as e x g, where 'e' represents the elasticity of marginal utility to increased consumption, and 'g' represents the per capita growth rate.

Clearly, with the anticipated growth in the economy, the future income will be less valuable and has to be discounted. Thus, CRI represents the distributional weighting to income transfer between generations. Thus, CRI can be estimated as ($(1 + g)^e - 1$) or as (e x g). The annual compound growth rate envisaged in the Plan Document 1980-85 up to 84-85 is 5.20 percent and 5.5 percent thereafter. An average growth rate of 5.35 percent has been assumed for this study. The average per capita GDP growth rate envisaged is 3.5 percent. The minimum value of CRI is set by (S x q) which works to 4.8 percent. Thus the minimum value of 'e' is obtained as 1.37. The normal value of 'e' is expected to be in the range of 1 to 3, depending on how egalitarian the society is. The maximum value of 'e' is obtained by observing that the CRI assumed should give plausible levels of P-investment. Also, the critical consumption levels (CCL) obtained using P-investment and Global Distribution measure should not be far different from the 'reference income level' adopted by the domestic government. The only case where significant difference between CCL and reference income level (RIL) adopted by the government is tolerated will be when the government places a high implicit value on 'e'.

Thus the maximum value of 'e' is derived using an iterative procedure so that the CRI obtained gives a plausible P-investment value.

To obtain P-investment values, we need an estimate of 'g' as a fraction of 'W', which one can obtain in a roundabout way. Indian Labour Year Book[1], published by the Labour Bureau gives the per capita earnings of employees in manufacturing industries in 1975 price levels statewide and industry-wide. An examination of these with the agricultural wages (both in cash and in kind) suggest that a plausible value of 'g' can be W/2. P-investment can now be computed for different CRIs as all the parameters necessary to compute P-inv have been derived. P-investment figures for different values of CRI are shown below:

---

1. Indian Labour Book, Government of India, Labour Bureau, 1980, pp. 28-29.

CRI	P-investment
11%	1.32
10%	1.58
8%	2.56
6%	6.83

Clearly, the CRI which gives plausible value of P-inv lies in the range of 10-11 percent. Thus the plausible elasticity of marginal utility to increased consumption works out to 3.

Shadow Wage Rate

In employing agricultural labor, agricultural workers gain (W - Z) and the economy loses W. The net loss in aggregate consumption:

$$\overline{W} = -(W - g) + (1 + S)W + S\ \text{P-inv}\ W$$

$$\overline{W} = Z + S(\text{P-inv} - 1)W$$

Here, due to lack of data the study assumes equal weight for agricultural workers' consumption and the consumption of the government. Thus, the above expression has to be adjusted by the following factor:

$$\left(1 - \left(\frac{\text{Critical consumption level}}{\text{Unskilled rural wages}}\right)^{e}\right) \quad (W - Z)$$

For a plausible value of P-investment of 1.32 and for g = 0.5W, the shadow wage rate is 0.6 times the market wage rate.

Regional and Rural Shadow Wage Rate

The economy-wide shadow wage rate will suffice as a good approximation for an industrial project being set up in the urban area. However, in rural areas due to the absence of stringent minimum wage legislation in rural areas the difference between shadow and market wages is not

significant. A technical working paper of the Planning Commission has worked out the SWR for three states as follows:

	Estimate 1	Estimate 2	Estimate 3
Andhra Pradesh	1.00	1.00	1.00
Maharashtra	0.76	0.74	0.76
Punjab	0.94	0.94	0.94

Source: "Technical Working Paper," The Planning Commission (1974).

In terms of the numeraire adopted for this study, the SWR will be different, as it will be P-investment times SWR derived using the Little & Mirlee numeraire. As the rural SWRs are nearly the same as market wage ates, no detailed corrections have been carried out.

Accounting Rate of Interest

The accounting rate of interest (ARI) can be defined as the productivity of the current investment in terms of the numeraire which is savings expressed in foreign exchange. Ideally, the ARI should equal the real rate of return on marginal investment in the public sector when it is evaluated using accounting prices.

The Planning Commission uses a 12 percent discount rate as the approximate cut-off rate to select projects. It has been found that assumption of a lower discount rate would mean rejection of high yielding projects which are proposed at the end of the plan period. A higher discount rate as a cut-off rate can leave planned resources unutilized. Hence, the social discount rate is used as a budgeting mechanism.

An alternative way of estimating the accounting rate of interest uses the fact that investment is valued at a premium over current consumption and that the divergence between CRI and ARI will diminish linearity over time until it disappears in T years. Here 'T' is chosen as the period over which savings become optimal. It can be shown that

$$\text{P-investment} = (1 + 1/2(ARI - CRI))T.$$

It is assumed that it will take fifty years for savings to become optimal when the ARI works out to 12 percent.

Alternatively, if the government is borrowing heavily from abroad, ARI can be estimated as the marginal cost of such borrowing. One way of estimating the marginal cost of such borrowing would be to look at interest charges on Euro-currency loans. The prevailing interest rates on Euro-currency loans is roughly 1 3/4 percent points above the London inter-bank ordinary rate (LIBOR) (9-10 percent) and thus an estimate of ARI based on marginal cost of borrowing can be 11 percent.

This study assumed a value of 12 percent of ARI as plausible.

Critical Consumption Level

The critical consumption level (CCL) is defined as that level of per capita consumption at which the government values private consumption just as much as public income.

An independent estimate of CCL is derived by examining government policies. Since one of the prime objectives of the domestic government is to reduce the percentage of people living below the poverty line, the poverty line can be used as approximation of reference income level.

Alternatively CCL can also be derived from Global Distribution Measure (D). 'D' is related to the distribution of consumption parameter and GINI coefficient as follows:

$$D = \frac{\sigma^{e} (\sigma - 1)^{1-e}}{e + \sigma - 1}$$

where

$$\sigma = \left(\frac{1 + GINI}{2\ GINI}\right)$$

and e = the elasticity of marginal utility to increased consumption.

For a GINI coefficient (World Bank, India Occasional Papers, 1978) of 0.28 works out to 2.29 and D works out to 1.68. D is related to CCL by the following relationship:

$$D = \left(\frac{\bar{C}}{CCL}\right)^{e}$$

The critical consumption level computed in the above manner works out to Rs. 1,250 per year or 84 percent of average per capita GDP.

The alternative way of computing CCL is to use the relationship between CCL and P-investment. For instance, if the adjustment factor for consumption is ignored it can be shown that

$$CCL = \bar{C} \left(\frac{1}{\text{P-investment}} \right)^{1/e}$$

where $\bar{C}$ represents per capita GDP.

The CCL, given a P-investment value of 1.32, works out to Rs. 1,365 per year and goes down to Rs. 1,068 per year for a P-investment value of Rs. 1,068 per year.

The poverty line has been used as a reference income level in view of the government policies which have accorded the highest priority to reduction of poverty. Also, the implicit assumption of a high value for 'e' suggests the plausible value of reference income level as the poverty line and thus this has been adopted as the reference level for the study.

Poverty line estimates in 1979/80 price levels statewide updated using the consumer price index for agricultural labor are shown below:

Maharashtra	Rs. 672/year
Punjab	Rs. 687/year
Andhra Pradesh	Rs. 582/year

Appendix C

Calculations of financial NPV, economic NPV, and economic NPV adjusted for savings and income distribution for the village of Kampbalapadu.

Kampbalapadu Village

Capital Cost Computation

LT lines* 2.75 km	Rs. 62,425
HT lines* 2.80 km	Rs. 61,320
Distribution* transformers 50 KVA	Rs. 15,000
	Rs. 138,745

Capital Phasing

I year	Rs. 34,686
II year	Rs. 34,686
III year	Rs. 27,749
IV year	Rs. 27,749
V year	Rs. 13,875
	Rs. 138,745

Sales Realization

Connections	Number	Units (kWh) consumed	Sales realization (Rs.)
Domestic	19	4,560	2,189
Agricultural	1	1,250	200
Industrial	2	4,800	2,304
Commercial	--	--	--
		10,610	4,693

OPERATING COST:

Total yearly electrical energy cost for the village:

38 paise/kWh X 10,610 = Rs. 4,032

Operations and maintenance cost @ 3% of capital cost = Rs. 4,153.

Year	Capital cost (in Rs.)	Cost of electrical energy (in Rs.)	Operations & maintenance cost (in Rs.)	Revenue from sales of units (in Rs.)
1	34,686			
2	34,686			
3	27,749			
4	27,749			
5	13,875	806	4,162	939
6	--	1,613	4,153	1,877
7	--	2,419	4,153	2,816
8	--	3,226	4,153	3,754
9	--	4,032	4,153	3,754
10	--	4,032	4,153	4,693
--	--	--	--	--
--	--	--	--	--
--	--	--	--	--
34	--	4,032	4,153	4,693

Note: 1. Useful life, 30 years of operation.

2. Production build-up as shown in table above.

KAMPALAPADU

	At 0% discount rate (Rs)	At 12% discount rate (Rs)
Capital cost	138,745	103,860
Operating cost		
Electrical energy cost	112,896	16,529
Operations and maintenance cost of maintaining distribution network	124,590	21,260
Sales realization through sale of electrical energy	131,404	19,240
Financial NPV	-244,827	-122,409

Switch in cropping pattern is the benefit, that is, in three acres, 75 bags of rice (7,500 kg of rice) are grown in place of groundnuts.

An approximate value of benefits is computed as follows:

Commodity	Quantity	Border price without premium	Value (in Rs.)
Rice	7,500 kg	Rs. 1.2/kg	9,000
Fertilizers	300 kg	Rs. 128.5/100 kg	386
Pesticides	Rs. 17/acre	--	51
			8,563

Value added including a premium on foreign exchange = Rs. 10,704

Value of groundnut production lost at the rate of 500 kg per acre in border price with a premium of 25% = Rs. 7,375

Cost of inputs (nontradeables) in groundnut production = Rs. 65

Net value of groundnut production = Rs. 7,310

Incremental value added = Rs. 10,704 - 7,310 = 3,394

Incremental expenditure on unskilled labor at the rate of Rs. 250/labor/year and a productivity of 15 quintals*/acre/labor

$$= \text{Rs. } 250 \times \frac{75}{15} = \text{Rs. } 1{,}250/3 \text{ acres}$$

Shadow wage rate - 1 X 1,250 = Rs. 1,250/3 acres

Net profit in border prices due to switchover = Rs. 2,114/year

Present value of net profit in border prices over useful life = Rs. 8,789

Preliminary economic NPV using 12% discount rate = Rs. 113,620

---

* One quintal equals 220 pounds.

Landowners' Benefit Due to Switchover from Groundnuts to Rice

The present value of financial benefit computed in the above manner using market prices instead of shadow prices using a 12 percent discount rate is Rs. 24,147. The high financial benefits are due to the low price at which groundnuts are sold in the market. As a result of these flows, the government loses Rs. 24,147 - 8,789 = Rs. 15,358, and the landowners gain Rs. 15,358.

Other Income Flows

1. Since the electricity board loses Rs. 122,409 on account of providing electricity to consumers, consumers gain Rs. 122,409.

2. Similarly, unskilled labor gains [(market wage rate - shadow wage rate) unskilled labor gain] while the government/project loses that much. Unskilled labor gains Rs. 250/year and the additional expenditure on labor is likely to be on the order of Rs. 1,250/3 acres. Since the income flow is defined as the difference between financial and economic prices, unskilled labor gains will be (market wage rate - shadow wage rate), while the government loses an equivalent amount. Since the rural market and shadow wage rates are the same, the income flow to unskilled labor from government is negligible.

3. The final income flow to be tapped is that of consumers from landowners. Landowners are required to incur a private investment of Rs. 3,900 at the beginning of the operation period for a pumpset and thereafter incur an operating expenditure of Rs. 1,100/year for fifteen years (a pumpset's useful life). Then the landowner invests in another pumpset for the remaining fifteen years. The present value of this expenditure stream works out to Rs. 6,594. The gain on account of purchase goes to the consumer class.

The various gains/losses can be summarized as follows:

	At 12% discount rate
Project loss to consumers	-122,409
Consumer gain from project	+122,409
Consumer gain from landowners	+6,594
Landowners gain from government	+15,358
Government loss to landowners	-15,358
Unskilled labor gain from additional work	negligible

The savings adjustment factor for project and government = P-investment - 1 (assuming all public sector profits are saved).

$$\frac{MPC_i \times MP}{CRI - (MP \times MPS)} - 1$$

where:

MP = marginal product of capital
CRI = consumption rate of interest
MPC = marginal propensity to consume
MPS = marginal propensity to save

The marginal propensity to consume for landowners and consumers is assumed to be 0.80 (see DasGupta, 1980). In view of the skewed income distribution--with higher income gorups being responsible for the bulk of the income--the assumption may not be unrealistic. Thus the adjustment factor for consumers and landowners is

$$\left(\frac{0.82 \times 0.12}{(-0.11 - 0.12 \times 0.18)} \right) - 1 \qquad = 0.11$$

Thus the adjustment factor for government and project is 0.32.

For instance, the government and project lose Rs. 137,767; the savings adjustment loss is Rs. 44,085; consumers and landowners gain Rs. 137,767; the savings adjustment gain is Rs. 15,154; the net savings impact is - Rs. 28.931.

Income Distribution Impact

1. Income distribution weight for the landowners' class is negligible due to the high value for 'e' and the low value for 'CCL.'

2. For unskilled workers, the weight is

$$\left(\frac{\text{Reference income level}}{\text{Unskilled labor wages}} \right)^e = 0.32$$

Thus the adjustment factor for unskilled labor = +0.32 = 1 = -0.68.

3. For the consumer class, the adjustment factor is computed as follows:

$$\left(\frac{\text{Reference group income}}{\text{Per capita income}} \right)^3 \times D \Bigg) - 1$$

Where D is Global Distribution Weight, which gives a higher weight to the consumer class, as it comprises a large number of 'poor' consumers.

$$\left(\left(\frac{582}{1484} \right)^3 \times 1.68 \right) - 1 = 0.06 - 1 = 0.10 - 1.00 = -0.90$$

Income gained by consumers is Rs. 129,003.

Adjustment needed is -116,103.

Income gained by landowners is Rs. 8,764.

Adjustment needed is -8.764.

Income gained by workers is negligible and no adjustment is needed to the class. Total adjustment for income distribution effect = -124,867. Thus the results can be summarized in the following fashion:

Financial NPV	=	Rs. -122,409
Preliminary adjusted economic NPV	=	Rs. -113,620
Adjusted eocnomic NPV for savings impact	=	Rs. -142,551
Adjusted economic NPV for savings and income distribution impact	=	Rs. -267,418

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Part 2

COST EFFECTIVENESS

OF DECENTRALIZED ENERGY SYSTEMS

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Chapter 1

INTRODUCTION

Traditionally, energy studies have focused upon efficient resource allocation. In view of the recent concerns of developing nations regarding reduction of poverty, aspects of income equity are also being appraised. Income distribution is being analyzed as governments increasingly apply project findings in order to achieve better intra- and inter-temporal income distribution. Decentralized energy sources should also be analyzed to judge the cost effectiveness of these options compared to a centralized grid supply.

Method of Analyzing the Cost Effectiveness of Decentralized Energy Systems

The decentralized energy systems analyzed in the report are as follows:

1. Biogas systems in conjunction with generation units
2. Windmills
3. Solar systems.

The above systems have been analyzed as alternatives to centralized grid energy supply in terms of cost effectiveness. For the purpose of this study, the cost of providing electricity to rural areas has been computed by identifying a cost minimization set. Here energy projects are considered nonbasic projects, that is, shortages are allowed to occur if no project belonging to a cost minimization set is available to fill the gap. The energy available at the entry point of a rural distribution system is measured in terms of the social cost of meeting the incremental demand from a cost minimization project at the social discount rate which takes into account investments (capital and operating) required up to the distribution stage. Investment for rural distribution is considered as location specific (depending on consumer density, type of load connected, distance

from central grid, and so forth). Social cost of electrical energy distributed, per kWh, is then computed taking into account investment in a rural distribution network, operating and maintaining the network and the social cost of energy at entry point. This is used as a reference social cost for selection of any decentralized system. If the cost of providing electricity through a decentralized system is comparable to or less than the cost of meeting requirements from the centralized grid, then the decentralized system is chosen over the centralized system.

The approach adopted by the study allows for a detailed sensitivity analysis to answer questions such as:

1. At what distance from the centralized grid do the various decentralized options become attractive compared to centralized grid supply?

2. How would decisions change in response to increased demand for electrical energy with and without increase in connected load?

The sensitivity analysis makes it possible to outline broad cost effective policy strategies for meeting the demand of electrical energy. However, it should be noted that the computations and policy outlines need constant monitoring to take into account technological advancements in the development of decentralized energy systems.

The methodology is broad based and is detailed to make it possible to include additional alternatives for analysis as they arise. The comparisons are made at village level.

The above approach assumes that the decentralized energy system forms a part of the cost minimization set if the cost of meeting the demand from this source is comparable to or less than that of the centralized system. Shortages are allowed to occur only if no suitable alternative for providing electricity at the reference social cost is available. Hence, choice of decentralized grid can be sub-optimal if all available technological options are not considered. The costs of decentralized systems computed in the report are based on costs at 1979/80 price levels and based upon technological development levels prevalent at the time of the study. However, the above approach is modified to consider a decentralized energy option as an intermediate solution by considering the

possible net social benefit based upon cost of one kWh of energy. If a centralized grid supply is likely to be available after say, "X" years, and if the pay-back period[1] in social terms (taking into account time value) is less than "X" years, then the decentralized system is considered as an intermediate solution.

Purpose of the Study

The purpose of the study as the title suggests is to determine the cost effectiveness of decentralized energy options. It does not examine the social profitability arising out of electricity in rural areas (except in cases where it is thought of as an intermediate solution before a centralized grid becomes operational). The major goal of the study is to delineate costs (capital and operating) at the village level so that options for use of decentralized/centralized energy systems are available as and when new villages are being considered for electrification. Although it may be theoretically attractive a priori to consider a set of decentralized/centralized options over the planning period for different locations, this study assumes that such an approach may not be feasible since villages become eligible for electrification one by one. Hence the methodology has been chosen to incorporate this real life constraint into the policy options. As already pointed out, decisions must be revised in light of technological advancements in decentralized energy systems.

This study examines in detail the biogas alternative as technology is proven and commercial viability becomes well established. The study also examines the cost of providing electrical energy through windmills and solar systems based upon tentative cost estimates available to date. Combinations of systems (such as biogas for firing a pumping motor in combination with diesel fuel) have not been considered due to a lack of reliable data. However, with reliable data, these can be analyzed in terms of their cost effectiveness vis-a-vis other systems.

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1. For proper interpretation of pay back period cited here please refer to Venkatesan (1981).

Organization of the Report

Chapter 2 contains a comprehensive literature survey examining the strengths and weaknesses of various studies in order to design a suitable framework for analysis. Chapter 3 details the methodology adopted, taking into account the strengths and weaknesses of various approaches outlined in chapter 2. Broad indications for adjustments carried out for social cost benefit analysis are also indicated. The chapter also focuses upon the development of an "Investment Index" to update capital costs to the base level (that of 1979/80 price levels) and the derivation of an economy of scale factor for biogas systems based upon updated costs. The findings are summarized at the end of the chapter. Chapter 4 briefly examines the policy implications of the findings from chapter 3. The appendix to the report details the computations.

Chapter 2

SURVEY OF THE LITERATURE

The search for alternative sources of electrification, particularly in rural areas of India, has gained momentum in recent years. One factor has been the inability of India's developmental facilities to meet goals set by the Rural Electrification Corporation. Another equally important factor is the continuous upsurge in the price of oil. These and other considerations for improving the primary sector economy (which still involves the majority of India's population) have created an urgent need to find alternative sources of electrification and thereby hasten the process of rural development. In doing so the underlying emphasis is on the cost factor. As a result, the possible alternative sources appear to be natural resources such as wind power, hydro power, solar power and conversion of animal waste (dung) to produce gobar gas. These sources, apart from being abundant and non-perishable in nature, are also environmentally acceptable. In a way, they are natural choices available to the decisionmaker.

In the past, conscious efforts have examined various renewable supply options that appear feasible for satisfying rural energy needs. Most of the studies conducted earlier broadly indicate widespread shortages of traditional fuels and point out the importance of non-conventional energy sources as options available to the decisionmaker (World Bank, 1979; UNCTAD, 1978). The question of meeting rural energy demand acquired importance in India beginning with the Fourth Five Year Plan (Planning Commission, Government of India, 1965) and resulted in the government's launching a large number of rural electrification programs. Numerous studies emerged analyzing improvements and beneficial changes due to rural electrification (Planning Commission, Government of India, 1965; SIET, 1980; REC, 1979). The single characteristic feature under investigation in these studies was the impact of rural electrification upon social profitability. Unfortunately, none of the studies considered decentralized

energy systems such as biogas, wind power, and solar power as options to the centralized grid system or attempted to evaluate them on the basis of cost. Although studies have been reported on cost-benefit analyses of rural electrification schemes (SIET, 1980; REC, 1979), there is a conspicuous absence of a rigorous social cost-benefit analysis from the viewpoint of the total economy, isolating transfer payments and value inputs. Besides, various alternative options are often not considered. Any decisionmaking process becomes sub-optimal if all possible alternatives are not properly considered for analysis. It is in this context that the present study attempts to assess, purely on a cost basis, various sources of energy which can be tapped. The cost prospects for various renewable energy sources as alternatives to a centralized grid system which are considered in the present study are as follows:

1. Biogas system in conjunction with a generation unit
2. Windmill--horizontal axis--exclusively for pumping water from bore wells
3. Windmill--vertical axis--for electricity generation
4. Solar thermal system
5. Photovoltaic system.

Cost assessment is difficult in general and it is even more so in the case of renewable energy sources because the nature of much use of renewables often makes any analysis ambiguous. For instance, cost comparisons are complicated by competing technologies and conflicting operating experiences. The present study overcomes all these difficulties through the mechanism of a rigorous cost benefit analysis considering options at the village level. For instance, investments have been considered at the village level for identification of a cost minimization set to arrive at cost per kWh including annutized capacity expansion cost. Furthermore, detailed sensitivity analyses have been carried out to determine how decisions are affected by change in input parameters and energy demand.

At this juncture, it would be worthwhile to review some of the studies that have appeared in the literature on the cost prospects of various

renewable energy sources to provide a backdrop to the present study and to design a suitable methodology to remove the inadequacies prevalent in some of those studies.

Biogas

One such nonconventional means of providing electricity for India's villages is the use of animal, human and perhaps some form of vegetable wastes to make methane, a fuel which can be used in small generators located in or near the communities served. Much of the activity in the development of biogas has been in India. A study conducted by the National Academy of Sciences (NAS, 1977) shows costs for 10 projects in Uttar Pradesh ranging from 2.6 to 6.7 rupees per thousand cubic feet of gas produced. Large numbers of similar cost estimates for direct use of biogas have been calculated for different areas such as Tanzania, China, Pakistan, and the results appear to be consistent (NAS, 1978; Pakistan, 1978; Khaskari, 1975). Very few cost estimates are available for indirect use of biogas, such as through electricity generation. Model estimates made for Tanzania indicate cost per kilowatt hour as large as 220 mills or about $61 per gigajoule (NAS, 1978). Other estimates have put the cost of electricity from biogas at 151 mills per kilowatt hour or more (Smith, 1977). These estimates are somewhat higher than those made for a project in Sri Lanka (Smith, 1977) where the cost estimate was put at 121 mills per kilowatt hour.

A considerable amount of research and a large number of pilot projects, especially in India, have been carried out for biogas with indigenous technology. The results show considerable reduction in capital cost of equipment.

A study conducted by C. R. Prasad, K. K. Prasad and A. K. N. Reddy on "Biogas Plants: Prospects, Problems and Tasks," arrives at the cost per kWh of electricity produced from biogas as Rs. 0.11 (Prasad, Prasad and Reddy, 1974). The study concludes with optimistic prospects for biogas plants for electricity generation as well as for multipurpose units. However, the study does not take into account the use of generator sets requiring huge sums of capital expenditure including the operating and

maintenance costs involved. With the inclusion of these costs the picture can be different.

In two other recently conducted studies, namely, "A Pilot Project to Investigate a Decentralized Energy System," by the State Planning Institute, Uttar Pradesh (Ghate, 1979); and "Biogas Versus Large Scale Power," by Wallace E. Tyner and John Adams (Tyner, 1978), cost estimates per kWh of electricity have been given based on the assumption that all the gas produced is utilized in electricity generation. The cost estimate of the former study is around Rs. 0.35 per horsepower hour, while that of the latter is around 5.1 cents per kWh or approximately Rs. 0.51 per kWh. Some other experimental data provided by Corporate R&D, BHEL (Gupta, 1980), also estimate the cost to be Rs. 0.85 per kWh.

The distinguishing features of this study are as follows:

1. Biogas in conjunction with a generator has been considered to estimate the cost per kWh generated;

2. Switching values for input parameters have been computed beyond which the decision changes from centralized to decentralized or vice-versa;

3. Biogas unit has been considered solely for generation of electricity and not as a multipurpose unit to take care of real life operational constraints such as availability and collection of dung. In order to emphasize the operation of real life constraints, a survey of a few villages in Karnataka has been conducted to assess dung availability.

Windmills

Windmills are the other alternative considered as a non-conventional source of meeting energy requirements of a village. Windmills with horizontal axes for pumping water and windmills with vertical axes for supplying mechanical and therefore electrical energy are an established technology. Within the past decades, the National Aeronautical Laboratory at Bangalore and Corporate R&D of BHEL have produced horizontal axis windmills using indigenous technology and material and have successfully tested them. The cost estimate for one such windmill as quoted by R&D of BHEL is approximately Rs. 10,000. A report on windmills and wind energy by Gupta (Gupta, 1980) treats the history of windmill development and the

state of the art to date. It also outlines the potential of wind power and the means for utilizing it most economically. Indigenous wind technology also exists in Thailand, where windmill driven "water ladders" have been utilized and cost estimates appear to be quite competitive. The unique feature of the present analysis with regard to horizontal axis windmills is that the system has been viewed as an "intermediate solution," and cost per kWh has been considered in equivalent terms to that of a power driven motor in order to make meaningful comparisons.

Vertical axis windmills can, of course, generate electricity, but the electricity option is relatively complicated and requires, in general, more engineering expertise for maintenance. Indeed, maintenance and distribution system management problems could form severe obstacles to the use of wind electric generators. With the present designs, a fairly large economy of scale seems to exist in producing wind convertors (Gupta, 1980). However, even small units of 15-18 kilowatts have been quoted as low as $500 or $600 per kilowatt (excluding the cost of towers). In India the estimated cost of a windmill with such a capacity fabricated by R&D of BHEL is approximately Rs. 50,000 including structural works. For one theoretical study in Tanzania (NAS, 1978) the unit cost for wind-generated electricity on a small scale was put at 180 mills per kWh. A considerable amount of research work is in progress in India and other developing countries and it is expected that improvements in design, use of indigenous and local materials and more emphasis on low wind speed technology would bring costs down considerably.

Solar

Direct use of the sun provides sufficient energy for cooking and other rural life functions in villages. Solar collectors are particularly well suited to crop drying. Solar heat can also be of use in providing a clean water supply or by providing pumping of potable water for irrigation. However, cost estimates provided by various experimental designs indicate solar methods to be highly uneconomical. For example, the cost per kilowatt of mechanical power provided by Flat Plate pumps is about $25,000 (Walton and coauthors, 1963, p. 11). One theoretical calculation for

Tanzania (NAS, 1978) where solar has been proposed for the refrigeration of fish, places the cost per kilowatt hour at 12 cents.

Another possibility for household energy from solar is photovoltaic electric power. The cost of energy from photovoltaic cells is presently rather high. It has been estimated that at a cost of $20 per peak watt, power from photovoltaic cells for typical installations might be $5.5 per kilowatt hour (Weiss and Pak, 1976, p. 5). In theoretical studies for Tanzania (NAS, 1978, p. 37), photovoltaic arrays supplying 300 kilowatt hours daily would deliver electricity at about $1.20 per kilowatt hour at $20 per peak watt array cost.

Other calculations have been carried out for a hypothetical village in India. Costs of photovoltaic, compared to other sources, as usual depend on the size and pattern of the load. For a motorized potable water supply, the photovoltaic cost at 50 cents per peak watt has been estimated to be 12 cents per kWh (Smith, 1977, p. 50).

Solar thermal generators, using the sun's heat to generate steam or some other vapor in order to drive ordinary turbine generators, could also be used to supply electricity. One demonstration project in Sri Lanka sponsored by UNEP combines both solar thermal and photovoltaic systems and a wind generator with a back-up biogas generator to generate electricity for lighting and other purposes in a small village (Smith and Allison, 1978). The unit cost of energy from the projected system is, according to a lower estimate of capital costs of $2,000 per kilowatt, 48.6 mills per kilowatt hour.

Small Scale Hydroelectricity

Small scale hydroelectric facilities can supply electricity for irrigation, potable water pumping, or lighting purposes. In the context of developing areas, development of this supply source has occurred in China, Tanzania and Pakistan. Cost of small scale hydro installations vary widely since they are highly location specific. Present costs quoted by developing countries for power generation from such systems range from 45 to 100 mills per kWh (Overseas Development Council, 1977, p. 19).

The present study does not include small scale hydroelectric as one of the options for renewable energy in its framework of analysis since the

questions of reliability, maintenance, technology and seasonal flow are especially critical for this option and further, there is a shortage of field data.

In this study, costs of the various non-conventional sources of electricity are found to be based upon supplying the proposed requirement for a village as currently met by the Rural Electrification Corporation's conventional system. Cost per kilowatt hour has been used as a guiding criterion for evaluating alternatives. The technique adopted is outlined in great detail in the subsequent chapter on methodology. Principally the benefit cost technique adopted allows systems to be evaluated from the standpoint of individual villages. The study also includes analysis of break-even distances which would permit decisionmakers to select a system that would be cost effective.

Chapter 3

METHODOLOGY OF ANALYSIS

Decentralized Systems

Decentralized systems analyzed for cost effectiveness are as follows:

- Biogas system in conjunction with a generation unit
- Windmill--horizontal axis--exclusively for pumping water from bore wells
- Windmill--vertical axis--attached to motor/generator, control module, storage batteries to DC loads or to AC loads along with an inverter
- Solar system thermal unit
- Solar system photovoltaic unit.

The guiding points behind the choice of these decentralized systems were:

1. Ease of applicability and installation
2. Ease of maintenance
3. Appropriate technology
4. Location conditions.

For instance, a horizontal axis windmill to pump water for agricultural purposes can be designed with indigenous materials available in the villages where wind velocity is in the range of 6 to 35 km per hour. This windmill can operate for an average 10 to 12 hours per day throughout the year. Here translatory motion is converted into reciprocating motion and water is pumped out from the bore well. Fabrication of tower and windmill require only two weeks' time and can be established on any location within

a week. The windmill and tower do not require any special steel[2] and thus have locational flexibility. Thus this decentralized system can be considered as an intermediate solution before a centralized grid becomes operational so as to reap the significant social benefits arising from increased land productivity made possible by better use of water. The other type of windmill which produces electrical energy in conjunction with generator control module storage batteries, with or without inverters, is also considered as an alternative to a centralized grid supply as this serves the purpose of providing electricity for lighting, running pumps, and such, unlike the former system which can be used for only pumping water. However, such a system has many locational limitations because it requires high rpm and low torque systems (which means a wind velocity prerequisite of more than 12 to 15 km/hour). These windmill systems can be used only in villages which have the required wind velocity, whereas the former windmill system can be installed in any village.

Photovoltaic and solar thermal units selected for analysis are those that predominantly serve agricultural pumping facilities. Storage batteries absorb extra energy when pumps are not in operation and can provide limited lighting to a few households or operate one or two drinking-water pumps. When extra energy is not needed for lighting or for operating the water pumps, it can be used for running a rice mill. The main reasons for limiting the analysis to the above solar systems instead of an array of storage batteries as a complete substitute for a centralized grid, are as follows:

- Since social profitability is significantly affected by additional agricultural production, the decentralized systems are to be designed to serve this main purpose;

- Other uses of electricity such as lighting become operational only when electrical energy is not needed for pumping. Thus storage batteries provided will absorb the additional energy necessary for use during night periods.

In other words, an extensive array of storage batteries to serve the twin purposes of lighting and running the pumpsets, is not part of the plan. The batteries provided are for absorbing the extra energy available over

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2. Extensive work has been done by Bharat Heavy Electricals Limited, Corporate R&D Centre, Vikasnagar, Hyderabad (mimeo).

the requirement for running pumpsets which are used incidentally for other purposes.

Thus the solar systems chosen for analysis are not complete substitutes for centralized grid systems but are cost effective solar systems which nearly substitute centralized grid systems in effecting social profit. Thus the choice of decentralized systems, a priori, are restricted to the following:

- Biogas--electric systems
- Windmill--horizontal axis, exclusively for water pumping
- Windmill--vertical axis, for lighting, pumping, and the like.
- Solar, thermal and photovoltaic, exclusively for agricultural pumping with incidental application for lighting, and so forth.

Methodology for Comparison with a Centralized Grid System

Social cost per kWh from decentralized systems is compared with a centralized grid energy supply to arrive at choice decisions. A sensitivity analysis is carried out to determine the optimal decisions when input parameters change. The implicit assumption in such an analysis is that cost effectiveness of decentralized systems is under examination and one is not concerned about the social profit arising out of use of 1 kWh. The other implicit assumption is that a decentralized system is considered as an alternative if it serves the main purpose (such as pumping water for agricultural purposes). In view of their flexibility of operation, economic attractiveness, and proven available technology, biogas systems are analyzed in detail. Since the technology for solar, thermal, and photovoltaic are still in developmental stages and commercial viability has yet to be proven, analysis is restricted to a general framework. Although windmill technology has been proven, the requirements of a vertical axis windmill which serves the twin purpose of lighting and pumping through electricity generation is complex in operation and is highly location constrained because of the wind velocity required for operation. Therefore windmill analysis is also carried out in a general context. Biogas systems

have been considered in greater detail for each village. Multipurpose biogas systems which serve various facilities as a supply of energy for cooking, and such other uses, have not been considered for analysis for the following reasons:

- Availability of dung becomes the main constraint for design of larger biogas units to serve multipurposes;
- Economy of scale by use of larger biogas systems are not going to affect the economies of electricity generation as the capital cost of a biogas system is not so significant a component as the remainder of the system, such as the generation unit and LT lines;
- Social constraints in operating community biogas units for multipurposes also points out that systems for generation of electricity above can succeed in the Indian village context which is characterized by various groups based on caste, creed, and economic status.

Thus the analysis considers only those biogas systems that are suitable for meeting electrical energy demand.

Cost of Rural Electrification per kWh from Centralized Grid

Theoretically it is desirable to set up a mixed linear integer programming model with project variables, such as size, location, timing, and technology, for decentralized and centralized systems so that, a priori, decisions as to which system should come, where, and at what point in time (so as to minimize the cost of meeting the demand), can be determined. However, such an approach is not feasible because projects are approved one at a time and data on the variables are not sufficient to make the exercise meaningful. Hence, the alternative is to set up a reference point for approval of projects as each one is evaluated. The reference point can be the social rate of return for projects producing tradeables. For projects producing non-tradeables and which are non-basic (in the sense that shortages can be allowed to occur) the cost of meeting demand is compared with that of a "cost minimization set" to approve or reject the project. Shortages are allowed to occur until such projects are identified. Since electrical energy is a non-tradeable one and since

electrical energy projects are not considered basic as are, for instance, projects conceived to supply rural drinking water, the approach is to identify the cost minimization set to accept or reject projects.

Again, two variants of SCB analysis are possible, one advocated by Little and coworkers as interpreted by Squire and Van der Tak (1975), and the other by Partha Dasgupta, A. K. Sen and S. Manglin as modified by John Hausen and John Weiss.[3] This study uses the latter methodology as it offers the scope to carry out analysis, stage by stage, and assumes a rather passive role of the project appraisal cell in altering policies of the government.

Since the bulk of electrical energy demand is met from thermal energy and since the Indian government plans to meet the additional requirement by setting up super-thermal projects, the cost of meeting the demand from these projects is identified as the social cost.

To compute the social cost of one kWh, investments in 1979/80 price of typical super-thermal projects have been identified. (Taxes and duties components have been deducted as these represent only transfer payments.) Credit for unskilled labor during construction is taken by using a shadow wage rate instead of market wage rate. The operating cost component, especially that of coal, is computed by identifying the social cost incurred to increase the mining of average grade coal by one ton for a pithead coal station. The cost of electrical energy computed in the above manner at the entry point to a rural distribution network works out to 38 paise/kWh.

The cost of electrical energy distributed to a village is, however, location specific, for it depends on distance of centralized grid, type of connections sought, load factor (kWh/kW), and others. Thus, cost of electricity for every village has been separately computed by identifying the capital and operating cost streams associated with rural electrification for every village. The rates assumed for laying LT lines, distribution transformers, and so forth, are listed in complete detail in the appendices.

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3. For details on reasons of choice of UNIDO Methodology, please see the discussion paper on SCB Analysis of Rural Electrification Schemes (1982).

The operating and maintenance cost is assumed to be 3 percent of capital cost based on experiences detailed in studies carried out in India. The energy demand for varying types of connections is also listed in the appendix. These are, again, dependent on actual energy consumption of villages in Andhra Pradesh.

The computations have been carried out at the social discount rate of 12 percent[4] and the useful life is assumed as 30 operating years. The phasing of capital expenses and production build up are as listed in the appendix. The cost per kWh is arrived at as the ratio as indicated under:

$$\text{Cost in 1979-80 constant prices per kWh to yield 12 percent social IRR}^{5} = \frac{\text{PV of capital and operating cost streams at 12 percent discount rate}}{\text{Discounted energy units at 12 \% discount rate}}$$

Cost of Decentralized Energy Supply per kWh

The Case of Biogas

Cost details of biogas systems available are based on 1973/74 prices. To update the costs to 1979/80 prices (so as to be comparable to the centralized case), an investment index was constructed. It is estimated that 66 percent of expenses for setting up biogas units are for civil and structural work and the remaining 34 percent, for equipment. The weighted index for civil and structurals based on the Reserve Bank of India study on general structures is indicated in the appendix. The composite indices were calculated for the years 1973/74 and 1979/80 to arrive at indices for updating.

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4. For details on Social Discount Rate see the RFF report on social cost-benefit analysis of Rural Electrification Schemes (1983).

5. Discounting of energy units is done to arrive at constant rate per kWh to yield a desired IRR.

Determination of economy of scale factor and computation of cost for intermediate sizes. Since the equipment for biogas units is fabricated for every case separately, to arrive at the capital cost for different sizes, the following approach was adopted. Assuming that capital cost varies with capacity as indicated in the following equation

$$\text{Capital Cost in base year prices} - K_1 \text{ (capacity)}^a$$

where K is "constant" and "a" is the economy of scale factor, it is possible to compute the capital cost for any size provided constants "K" and "a" are known. Since cost estimates for 5,000 ft^3/day and 100 cft/day were available, the unknown parameters "K" and "a" could be determined. These are used for determination of capital cost of intermediate sizes.

Details of labor and maintenance costs for biogas units are listed in the appendix. Useful life of 30 years is assumed to be realistic for biogas systems. The construction period for setting up a biogas unit in conjunction with a generation unit and the laying of LT lines is assumed to be three years with operation commencing in the third year. The assumption is based on the performance of carrying out "intensification" projects by various electricity boards.

The production build-up assumed for a decentralized system is the same as that for a centralized system, the constraint being the demand pick-up from consumers rather than operational constraints of the system.

The electrical energy that can be generated from one cubic foot of gas is 0.15 kWh (see Reddy and Prasad, 1977). The capacity requirement of a biogas unit is determined based on the above assumptions. Although theoretically it may be possible to devise larger biogas systems to cater to all types of uses, the constraint on the availability of cowdung as raw material restricts these systems to supply of electrical energy only.[6] The social problems arising from the use of human waste and the practical problems involved in the collection of biomass makes it impracticable to think of a larger system based on supplemented biomass and human waste. The cost of the generation unit is assumed at Rs. 2,400/kW and connected

6. See appendices for discussions.

load has been computed on the basis of type of connection and number of connections (as shown in the appendices). The cost of providing LT lines is assumed to be the same as that for a centralized grid. The capital and operating costs' phasing, and energy distribution possible year-wise, are listed in detail in the appendices. Cost per kWh is computed at the social discount of 12 percent in the same manner as for a centralized unit.

Decentralized Unit--The Case of Windmills

In order to determine the attractiveness of using windmills as an intermediate solution before the centralized grid becomes operational, the case of windmill use exclusively for pumping water (by converting translatory motion to reciprocating motion) is also carried out. Since the bulk of social profit arises from increased agricultural production and switch in cropping pattern, the use of windmills as an intermediate solution deserves analysis. An approximate estimate of the cost of pumping water using this windmill is compared with the use of electrical energy to run an equivalent pumpset.

A windmill that can generate electricity for lighting as well as for running pumps is also considered for analysis. Since these windmills call for use of special fabrication materials and need wind velocity greater than 12 to 15 km/hour, the potential use of these windmills is constrained by the location. Costs involved for generation unit, controlling module, storage batteries and invertor are mentioned in the appendix. It must be mentioned that an invertor may not be necessary if there is a DC supply for lighting or running pumpsets. However, for heavy duty applications, an AC supply may be needed demanding an additional investment for invertors. While the useful life assumed for windmills is thirty years, storage batteries have to be replaced every four years. The operating cost would be the wages of one technician-cum-operator. The capital and operating cost flow streams are shown in the appendix. The cost per kWh is computed for the general case.

Solar Systems

Applicable solar systems can be categorized under two heads:

1. Solar thermal
2. Photovoltaic

In the former, radiated heat energy is used to super heat steam at 500°C, and at a pressure of 7 atmospheres, to run a steam turbine to generate electricity. In order to tilt the parabolic reflectors, a motor is necessary with a biogas system as auxiliary equipment. In the latter case, semi-conductors use the heat energy to develop voltage to supply electricity.

As indicated earlier, a solar system used for motors can be used to generate electricity for lighting during nights. Storage batteries are provided only to absorb extra energy produced and are needed for running pumpsets. These storage batteries can also be used to supply electricity for lighting, for running a drinking water domestic pumpset, or a rice flour mill during non-peak hours.

Sensitivity Studies

a. Sensitivity to connected load or scheduling of pumps:

To illustrate the sensitivity of computations to changes in connected load, various schedulings of pumps have been assumed to reduce connected loads and results are compared.

b. Sensitivity to change in HT lines:

Sensitivity studies to compute the extra length of HT lines (which makes the cost of providing electricity from either centralized or decentralized the same) is worked out for each case. For each km of HT lines, an investment of Rs. 21,900 over 3 years and an operating expenditure of 3 percent of investment over 30 operating years is assumed to arrive at the figures of extra HT lines that make the decision to use centralized/decentralized systems equally attractive.

c. Sensitivity to increased energy demand:

Detailed sensitivity studies have been carried out to assess how costs change with increased energy demand at village level. The sensitivity studies carried out are:

1. Increase in energy demand by 50 percent and 100 percent with increase in connected load (for instance, due to new connections).

2. Increase in energy demand by 50 percent and 100 percent without increase in connected load (for instance, better utilization of existing connections).

For every case the equivalent extra HT lines that make the switch-over from centralized to decentralized or vice-versa equally attractive is also worked out.

Comparative cost results are shown in the tables in chapter 4. Table 4-1 provides cost per kWh for centralized and various decentralized systems. Table 4-3 presents HT lines in km beyond which a decentralized unit becomes attractive.

Chapter 4

RESULTS ANALYSIS AND POLICY IMPLICATIONS

The study implicitly assumed that decisions on electrification from centralized grid vis-a-vis various decentralized energy systems will be made at such time as villages are evaluated for electrification. That is, it may be naive to expect that choice of candidates for electrification is possible through a programming exercise with project variants as location, centralized/decentralized systems, timing and size. This study does not measure the social profitability arising out of rural electrification but examines the cost effectiveness of various decentralized energy systems vis-a-vis centralized grid supply systems. In other words, the government a priori selects villages for electrification based on a broad social profitability analysis[7] but will make an additional analysis of cost effectiveness of decentralized systems vis-a-vis centralized systems. The only drawback of such an analysis can be that some villages could have appeared as candidates earlier as they may be socially more profitable with decentralized systems, but this study assumes that for realistic reasons, candidates for electrification have to be chosen as per social profitability due to electrification from centralized grid supply. For this purpose categorization of villages based on type of benefits expected, sociocultural background of villages can be carried out earlier as indicated in the report on "Social Cost Benefit Analysis of Rural Electrification Schemes" (RFF, 1983).

Centralized Grid Supply

To arrive at the cost of energy at the rural distribution point, a project belonging to cost minimization set was identified and the cost per

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7. See report on "Social Cost Benefit Analysis of Rural Electrification Schemes" (RFF, 1983).

kWh for energy supplied at distribution point was worked out at 12 percent social discount rate. However, the cost of electrical energy at the exit of distribution network is location dependent as it depends on total energy consumed, type of connections, and other factors.

For instance, the capital cost for rural distribution network can be identified as investments in:

1. High tension (HT) lines
2. Distribution transformer
3. Low tension (LT) lines

Since the bulk of the cost involved is in laying either LT or HT lines the variables that affect economics of energy supply from centralized grid are:

a. Distance from main grid
b. Type of connections (load factor kWh/kW)
c. Number of connections (LT lines required).

Thus the supply of electrical energy from the centralized grid may be attractive if: (a) the village is not located too far away from the centralized grid; or (b) if connected pumps are operated for longer periods; or (c) if LT lines laid are kept to a minimum because of customer density; or, (d) if energy consumed by the village is at a high level. In order to examine the validity of the above observations, a detailed sensitivity analysis has been carried out. Cost aspects of every case is detailed in the annexures. Table 4-1 indicates the cost per unit of electricity for the various cases.

The cost of providing electricity from a centralized grid for base case varies from Rs. 1.85 to Rs. 2.65 for the three villages analyzed. The highest cost is incurred in Satulran village which has more domestic connections. Further, the distance from the main grid to this village as compared to other villages is also greater.

A 50 percent increase in electricity demand along with an increase in connected load produced a decrease in cost per unit of about 15 to 19 percent from the base case. The decrease in cost per unit is as high as 26 to 28 percent if the increased energy demand is considered without increase in connected load. Increased energy consumption without increase in

Table 4.1. Results Summary
(Rs. per kWh in 1979/80 prices)

	Chennapuram	Satulran	Chingapalli
1. Centralized grid supply			
a. Base case*	1.35	2.65	2.45
b. Base case but increased energy demand by 50 percent along with increase in connected load	1.57	2.20	1.39
c. Base case but increased energy demand by 100 percent with increase in connected load	1.42	1.97	1.76
d. Same as (b) but without increase in connected load	1.36	na	1.76
e. Same as (c) but without increase in connected load	1.12	na	1.42
2. Decentralized grid system Biogas system			
a. Base case	1.96	1.80	2.06
b. Base case but increased energy demand by 50 percent along with increase in connected load	1.89	1.17	2.02
c. Base case but increased energy demand by 100 percent along with increase in connected load	1.87	1.75	2.00
d. Same as (b) without increase in connected load	1.39	na	1.51
e. Same as (c) but without increase in connected load	1.09	na	1.23
3. Decentralized grid system Windmill-horizontal axis (intermediate solution) "Equivalent" cost	0.90	0.90	0.90
4. Decentralized grid system Windmill-vertical axis	3.27	3.27	3.27
5. Decentralized grid system Solar thermal (approximate cost)	62.00	62.00	62.00
6. Decentralized grid system Photovoltaic (approximate cost)	21.00	21.00	21.00

Note: na = not available.

*The base case describes the villages in terms of actual consumption of electrical energy and otehr characteristics such as number and type of connections, distance from the central grid, population density. For further detail, see appendices.

connected load is possible if, for instance, pumps are operated for longer hours.

A 100 percent increase in electrical energy demand along with an increase in connected load showed a further decrease in cost per unit ranging from 23 to 28 percent from the base case. For the case without increase in connected load the decrease is as high as 39 to 42 percent from the base case. Decrease in cost per unit can be ascribed to the high fixed cost component in centralized grid investments. The significant decrease occurring in the case of increased demand without increase in connected load is due to the fact that investment in LT lines also forms a part of the fixed cost component.

Cost Effectiveness of Biogas Systems As an Alternative to Centralized Grid

The study assumes that an alternative biogas system will be used exclusively for the generation of electrical energy and not as a multipurpose unit because the dung requirement will far outstrip the supply (as an approximate analysis in appendix E based on a survey of seven villages in Karnataka indicates). For instance, for a family of five to six persons, gas required for cooking and lighting may be approximately 60 ft^3/day demanding a larger installation than may be feasible in view of the animal population in villages. On an average in India there is only one-half bovine animal per person, whereas at the minimum, for a gas generation rate of 6.6 ft^3/kg (dry-dung), one animal is required. In view of this, the study assumes that decentralized biogas units cannot be multipurpose in nature (although that may be desirable) because of insufficient supplies of dung. The other assumption is that the cost of dung collection is off-set by the value realizable from the by-product (manure). The assumption might not be realistic as the available evidence shows that a 60 m^3/day biogas plant, on an average, needs five lorry loads of dry-dung valued at Rs. 700/load for a week's duration. The manure available may or may not fetch more than the cost incurred in collecting dry dung for the digester.

The cost per kWh from a biogas unit is found to be in the range of Rs. 1.80 to 2.06 for the base case. The interesting observation that can be made is that cost per kWh is significantly lower for Satulran village which

has bulk domestic connections. This can be explained by the fact that the cost of a biogas unit as such is not so significant a component of total capital cost as are generation unit LT lines. Hence with lower connected load, cost per kWh from a decentralized unit is comparatively lower.

The cost per kWh decreases by 2 to 4 percent for a 50 percent increase in energy consumption with increased connected load, and to about 27 percent without increase in connected load. This reinforces the earlier observation that for lower connected loads, decentralized energy systems are quite attractive.

The cost per kWh decreased by about 3 to 6 percent for a 100 percent increase in energy demand with increased connected load, and to about 40 percent without increase in connected load.

For the base case, a decentralized energy system offers an attractive alternative to a centralized grid for Satulran and Chingapalli villages. Satulran has bulk domestic connections and is far away from the main grid, thus the cost per kWh from the decentralized energy system is significantly lower than the cost from the central grid supply. Although Chingapalli village does not have that many domestic connections (low connected load and lower load factor), because it is located far away from the centralized grid a biogas unit is attractive.

When demand for energy increases, the cost per unit comes down significantly in the case of a centralized grid, while any decrease in cost from the decentralized grid is marginal. For instance, for Chingapalli village, if the energy demand increases by 50 percent then the cost per unit from the centralized grid becomes less than the cost per unit from a decentralized energy system. However, if the energy demand increases without appreciable increase in connected load, the choice is not significantly different to that prevalent for the base case. Table 4-2 below illustrates these points.

Table 4-2. Comparative Electricity Costs for Chingapalli Village (Rs.)

	Centralized grid supply	Biogas energy supply
Cost per kWh base case	2.45	2.06
Cost per kWh when energy demand is increased by 50% from base case with increase in connected load	1.99	2.02
Cost per kWh when energy demand is increased by 50% without an increase in connected load	1.76	1.51

Source: Present study.

It may be of interest to study the break-even distance beyond which a decentralized biogas system becomes more attractive than a centralized grid system. Table 4-3 provides the break-even distance for various cases discussed in the study.

The break-even distance is the point beyond which the net present value of the capital cost for installing and maintaining the lines over thirty years is more than the net present value of operating the biogas system. The details of time profile of cost flows is shown in appendix B-2.4.

As the results in table 4-3 show, decentralized biogas systems become more attractive than the centralized scheme in a village such as Satulran with bulk domestic connections if the village is 0.4 km or more away from the central grid. With increasing demand for energy, break-even distance computed increases implying that a centralized grid becomes more attractive even if villages are far away from the main grid. For instance, if the energy demand increases by 50 percent, the break-even distance beyond which decentralized systems become attractive increases by 60 to 100 percent. These results show that for a village with high energy demand it may not be worthwhile to go in for a decentralized system even if it is far away from the centralized grid. However, even the break-even distance in km comes down marginally when increase in demand for energy occurs without increase in connected load.

Table 4-3. Results Summary: Break-Even Distance*

	Chennapuram	Satulran	Chingapalli
1. Base case	1.55	0.40	1.10
2. Base case but increased energy demand by 50% along with increase in connected load	2.50	0.80	1.80
3. Base case but increased energy demand by 100% along with increase in connected load	2.30	1.20	2.60
4. Base case with increased energy demand by 50% but without increase in connected load	1.48	na	1.20
5. Base case with increased energy demand by 100% but without increase in connected load	1.39	na	1.10

*Break-even distance from central grid to distribution point of village beyond which decentralized biogas system is attractive.

For Satulran village, computations were not carried out for cases without increase in connected load, as the bulk of connections are for domestic lighting.

Windmill--Horizontal Axis

The windmill with a horizontal axis (HA) operates a bore well to pump water without the intermediate stage of conversion to electrical energy. That is, translatory motion is converted to reciprocating motion to pump water.

This can be thought of as an intermediate solution in order to reap the social profit resulting from availability of water through the use of this system. Since social profit is affected significantly due to availability of water (and thus possible use of high yielding crop varieties and fertilizer) and consequent increased agricultural production, a horizontal axis windmill can be an intermediate solution if the cost of operation of the mill is comparable to the gross social profit.

The cost of kWh computed for this case is an "equivalent cost." The power of the windmill is expressed in kilowatts, or, to that of an equivalent energized pumpset. That is, the quantity of water pumped from

the windmill and the energized pumpset will be the same for a given amount of time. The cost per kWh computed in the above manner is termed an "equivalent" kWh cost.

A typical HA windmill installed by BHEL has been examined to arrive at the tentative equivalent cost per kWh. The equivalent cost per kWh works out to Rs. 0.90. This cost is considerably lower than the cost per kWh distributed from the centralized grid for the three villages under study. The main reason for high cost per kWh for the centralized grid compared to that of the HA windmill is due to the high investments in the rural electrification network.

However, it must be pointed out that substitution of the HA windmill for a centralized grid in terms of electricity for lighting, for instance, is not possible because highly agricultural operation or rural industrial operations could not be sufficiently supplied if such a substitution were to take place.

Table 4-4 below indicates the net social profit that can be obtained from two typical villages with differing nature of benefit resulting from electrification. This is used to compare with the cost of an "intermediate" solution.

Table 4-4. Net Social Profit per kWh

Village	Nature of benefit	kWh consumed per year	Discounted units over operating years	Net social profit (Rs.) over useful life	Net Social profit per Rs./kWh
Village 1	Cotton--decrease in risk and increased productivity	10,280	82,805	426,329	5.15
Village 2	Wheat/rice--increased productivity	286,420	2,307,113	2,716,630	1.18

Source: Venkatesan, R., and coauthors, "Social Cost-Benefit Analysis of Rural Electrification Schemes," for Resources for the Future (1983).

The net social profit per kWh ranges from Rs. 1.18 to 5.15 for the two typical villages shown above. The net social profit is obtained after recovering the cost of providing electricity at the social discount rate. Since the equivalent cost per kWh is even less than the cost of providing electricity from a centralized grid and since net social profit can be as high as Rs. 5.15 per kWh, the HA windmill can be considered as a viable intermediate solution to reap social benefit for the intermediate period until the supply from a centralized grid can be restored. Note that this result is conditional on a village meeting the wind velocity requirements needed to install an HA windmill and on the types of benefits that are expected. Note that this result is conditional on a village meeting the wind velocity requirements needed to operate a HA windmill and on the types of benefits that are expected.

Windmill--Vertical Axis

A vertical axis (VA) windmill can be used to generate electricity for small DC applications such as domestic pumps, lighting, and small agricultural pumpsets. It can also be used for heavy duty applications such as rural industries or bigger agricultural pumpsets after conversion of the energy with AC load through the use of an inverter.

The system incorporates a control module to take care of fluctuations in power due to varying grid velocities, and batteries to store DC energy. The VA windmill is the typical high rpm (revolutions per minute), low torque system needed for power generation.

The details of costs are furnished in appendix C-2. The capital cost stream takes into account the recurring capital investments on batteries over a useful life of thirty operating years. The cost per kWh to yield 12 percent on capital employed has been arrived at after considering the operating cost incurred in terms of the wages of one skilled operator. The cost per kWh works out to Rs. 7.27 for a typical case.

This cost is considerably higher than cost per kWh from the centralized grid and consequently this can be thought as an intermediate solution only in extreme cases where social profit is very significant. If the location constraints (such as the required wind velocity of 12 to 15 km/hour) are also considered, then use of this system as an intermediate solution or as an alternative to a centralized grid may not be worthwhile.

The break-even distance beyond which a VA windmill becomes an attractive option has not been computed as the cost difference between the centralized and decentralized system is significant.

Solar Thermal and Photovoltaic Systems

A typical solar thermal system of 15-18 kWh net output, capable of operating 6 to 8 pumps of 3 kW capacity each is considered for analysis. The same system can be designed such that the surplus power not used during peak sunshine can be stored to operate drinking water pump, rice mill and street lighting.

The technology is still in the developmental stage and the cost of producing power from solar energy is still prohibitively high and has yet to be commercially proven. The tentative cost details for solar, thermal and photovoltaic systems are given in appendix D. The cost per kWh is also significantly higher than the centralized grid supply, and thus these cannot be considered attractive alternatives to a centralized grid until a technological breakthrough has been achieved and the cost is reduced significantly.

Policy Implications

This section synthesizes the findings mentioned in earlier sections so that broad operational guidelines can be evolved for policymakers.

The cost of providing electrical energy from biogas units is quite comparable to the cost of providing electricity from a centralized grid. The cost of rural electrification from a VA windmill is significantly higher than that from a centralized grid. Considerable research is needed to bring down the cost of providing electricity from solar systems for them to be an effective alternative to a centralized grid supply. Optimizing the decentralized system by designing a larger biogas system for multi-purpose usage is limited in scope because of social and cultural factors and the unavailability of dung in sufficient quantities.

Typically, when electrical energy demand is in excess of 15,000 kWh/year, the cost per unit from a centralized system is considerably lower than the cost from any decentralized system. Today the average annual electricity consumption for the three villages considered in 10,647 kWh.

The response of cost per unit to increased energy demand, particularly with increased connected load observed through various sensitivity analyses, is significant in the case of centralized systems vis-a-vis decentralized systems. If the energy demand increase occurred without any increase in connected load, then the cost effectiveness of decentralized systems vis-a-vis centralized systems does not appreciably change from the base case.

A decentralized unit as an intermediate solution to maximize social profitability by utilizing ground water potential merits serious attention. The HA windmill which activates the bore-well seems to be the desirable decentralized alternative as the cost of pumping water compares favorably with alternative modes. Depending upon the nature of benefit and anticipated social profit, it is suggested that areas be prioritized for installation of HA windmills as an intermediate solution.

Break-even distance is one of the important factors to consider apart from type of connected load, load factor, and energy demand. This must be compared with the distance of the village to be electrified from the main grid.

Intermediate solutions in cases where the electrification from a centralized grid is expensive should be considered if the social profit to be reaped through the use of ground water is significant.

Before cost-effectiveness analysis can be conducted for a village, data must be collected on the following:

- Distance from the main grid
- Type of connections sought
- Distribution transformer capacity needed
- Probable layout of LT line distribution network
- Load factor
- Wind velocity and its variance over the year
- Number of sunshine days and hours of sunshine per day
- Indigenous technology, materials availability
- Sociocultural factors of village to be electrified

- Capital cost of producing HT lines, LT lines, distribution transformer, biogas system, photovoltaic system, solar thermal system, windmill (horizontal and vertical axes systems), and other

- Type of agricultural benefits that can be expected

- Acreage that will be brought under intensive cultivation and preliminary assessment of social profit

- A sample interview of villagers to estimate the electrification needed by villages

- Income distribution in the village, vis-a-vis, district/state/country, to estimate how far average profitability will deviate from actual profitability for the village

- Capital cost of installation of pumpsets, its maintenance cost, useful life of pumpsets, average acreage that can be brought under one pumpset

- Cost to the consumers for providing one-time connection charges in houses for lighting, to pumpsets in fields, and the like

- The types of possible cottage industries

- The ground water potential

Thus this study has examined in detail the cost effectiveness of providing decentralized systems as the alternative to centralized grid supply and the switching values in input parameters which affect such decisions. The study also dealt in detail with the role of decentralized systems as an "intermediate" solution before the introduction of centralized systems, where the opportunity costs (in terms of social profit) of not electrifying are very significant. The study has been designed such that it can be updated by construction of suitable indices as elaborated in the text for changes in relative price levels. The elaborate sections on sensitivity analyses also provide an analytical framework to assess the attractiveness of decentralized systems vis-a-vis a centralized system under changing conditions of demand and other factors.

Appendix A-1. Cost of Electrical Energy from Centralized Grid for Chennapuram Village

A. Capital cost of providing electricity to village from centralized grid

	Unit	Rate Rs./km	Amount in Rs.
HT lines	1.30 km	Rs. 21,900/km	28,470
Distribution transformers	25 kVA	Rs. 12,200	12,200
LT lines	1.84 kms.	Rs. 22,700km	41,768
Total capital investment:			82,438

B. Capital phasing

Year of construction	Amount in Rs.
1	20,610
2	20,610
3	16,487
4	16,487
5	8,244

C. Cost of electrical energy

1. Energy units consumed

Types of connection	Number of connections	Assumed units consumption/ connection/year	Total units consumed/year
Domestic	10	240	2,400
Agriculture	6	1,250	7,500
Industrial	1	2,400	2,400
Commercial	--	--	--
			12,300

2. Cost of energy delivered to the central distribution point of the village in one year

Year of construction	Units consumed/year	Cost in Rs/year
5	2,460	935
6	4,920	1,870
7	7,380	2,804
8	9,840	3,739
9	12,300	4,674

Appendix A-1. (Cont.)

D. Operations and maintenance cost: Rs. 2,473/year

Cash flow for computing cost/kWh

Year	Capital cost in Rs.	Cost of electical energy in Rs.	Operation and maintenance cost in Rs.	Units consumed kWh
1	20,610	--	--	--
2	20,610	--	--	--
3	16,487	--	--	--
4	16,487	--	--	--
5	8,244	935	2,473	2,460
6	--	1,870	2,473	4,920
7	--	2,804	2,473	7,380
8	--	3,739	2,473	9,840
9	--	4,674	2,473	12,300
"	"	"	"	"
"	"	"	"	"
"	"	"	"	"
34	--	4,674	2,473	12,300
				332,100 kWh

Discounted and capital energy costs

Discounted capital cost @ 12 percent discount rate	Rs. 61,710
Discounted energy cost @ 12 percent interest rate	Rs. 19,236
Discounted O&M cost @ 12 percent interest rate	Rs. 12,660
Total discounted capital and operating costs	Rs. 93,606
Discounted energy units @ 12 percent interest rate:	50,621 kWh
Cost/unit to yield 12 percent IRR	Rs. 1.85/kWh

Appendix A-2. Cost of Electrical Energy from Centralized Grid for Satulran Village

A. Capital cost of providing electricity to the village from the centralized grid for Satulran village

	Unit	Rate	Amount in Rs.
HT lines	2.1 km	Rs. 21,900/km	45,990
Distribution transformers	25 KVA	Rs. 12,200	12,200
LT lines	2.28 km	Rs. 22,910/km	51,756
			109,946

B. Capital phasing

Year of construction	Amount in Rs.
1	27,487
2	27,487
3	21,989
4	21,989
5	10,994

C. Cost of electrical energy

1. Energy units consumed

Types of connection	Number of connections	Assumed units consumption/ connection/year	Total units consumed/year
Domestic	30	240	7,200
Agriculture	--	--	--
Industrial	1	2,400	2,400
Commercial	4	240	960
			10,560

2. Cost of energy delivered to the central distriubtion point of the village in one year

Year of construction	Units consumed/year	Cost in Rs./year
5	2,112	803
6	4,224	1,605
7	6,336	2,408
8	8,448	3,210
9	10,560	4,013

Appendix A-2. (Cont.)

D. Operations and maintenance cost: Rs. 3,298/year

Cash flow for computing cost/kWh

Year	Capital cost (in Rs.)	Cost of electical energy (in Rs.)	Operation and maintenance cost	Units consumed (kWh)
1	27,487	--	--	--
2	27,487	--	--	--
3	21,989	--	--	--
4	21,989	--	--	--
5	10,994	803	3,298	2,112
6	--	1,605	3,298	4,224
7	--	2,408	3,298	6,336
8	--	3,210	3,298	8,448
9	--	4,013	3,298	10,560
"		"	"	"
"		"	"	"
"		"	"	"
34	--	4,013	3,298	10,560

Discounted capital and energy costs

Discounted capital cost at 12 percent interest rate	=	Rs. 82,301
Discounted energy cost at 12 percent interest rate	=	Rs. 16,516
Discounted O&M cost at 12 percent interest rate	=	Rs. 16,883
Total discounted capital and operating costs	=	Rs. 115,700
Discounted energy units at 12 percent interest rate	=	43,464 kWh
Cost/kWh to yield 12 percent IRR:		Rs. 2.66/kWh

Appendix A-3. Cost of Electrical Energy from Centralized Grid for Chingapalli Village

A. Capital cost of providing electricity to village from centralized grid

	Unit	Rate Rs./km	Amount in Rs.
HT lines	1.80 km	Rs. 21,900/km	39,420
Distribution transformers	25 KVA	Rs. 12,200	12,200
LT lines	1.50 Km	Rs. 22,700/km	34,050
			85,670

B. Capital phasing

Year of construction	Amount in Rs.
1	21,418
2	21,418
3	17,134
4	17,134
5	8,566

C. Cost of electrical energy

1. Energy units consumed

Type of connection	Number of connections	Assumed units/consumed connection/year	Total units consumed/year
Domestic	6	240	1,440
Agriculture	4	1,250	5,000
Industrial	1	2,400	2,400
Commercial	1	240	240
			9,080

2. Cost of energy delivered to the central distribution point of the village in one year

Year of construction	Units consumed/year	Cost in Rs./year
5	1,816	690
6	3,632	1,380
7	5,448	2,070
8	7,264	2,760
9	9,080	3,450

Appendix A-3. (Cont.)

3. Operations and maintenance cost: Rs. 2,570/year

Cash flow for computing cost/kWh

Year	Capital cost (in Rs.)	Cost of electical energy (in Rs.)	Operation and maintenance cost (in Rs.)	Units consumed (kWh)
1	21,418	--	--	--
2	21,418	--	--	--
3	17,134	--	--	--
4	17,134	--	--	--
5	8,566	690	2,570	1,816
6	--	1,380	2,570	3,632
7	--	2,070	2,570	5,448
8	--	2,760	2,570	7,264
9	--	3,450	2,570	9,080
"	"	"	"	"
"	"	"	"	"
"	"	"	"	"
34	--	3,450	2,570	9,080

Discounted capital and energy costs

Discounted capital cost at 12 percent interest rate	=	Rs. 64,129
Discounted energy cost at 12 percent interest rate	=	Rs. 14,199
Discounted O&M cost at 12 percent interest rate	=	Rs. 13,157
Total discounted capital and operating costs	=	Rs. 91,485
Discounted energy units at 12 percent interest rate	=	37,369 kWh
Cost/kWh needed to yield 12 percent IRR:		Rs. 2.45/kWh

Appendix B-1. Investment Index to Update Capital Cost of Biogas Systems to 1979/80 Base Year

Component of investent index	Weight	Price level 1973/74	Price level 1979/80
A. Construction			
Cement	0.10	110.0	229.4
Logs and timber	0.12	131.2	382.9
Iron and steel mfg.	0.12	130.5	212.5
Bricks and tiles	0.11	191.6	272.3
Lime	0.15	118.0	141.2
Sand	0.15	118.0	141.2
Unskilled labor wages	0.25	134.4	193.5
Composite[a]	0.66	132.5	215.1
B. Machinery	0.34	130.3	189.2
Aggregate index		131.8	206.3

[a]Civil and structural costs form 66 percent of total capital cost as available evidence shows (see Reddy, 1974).

Components of civil and structural cost have been obtained based on general civil structures. Banks: Reserve Bank of India--Investment Index Studies.

Appendix B-2. Cost Details of Biogas Systems

	5,000 ft^3/day	100 ft^3/day	60 ft^3/day
Capital cost (1973/74 prices)	Rs. 41,000	Rs. 2,500	Rs. 1,500
Capital cost (1979/80 prices)	Rs. 63,960	Rs. 3,900	Rs. 2,340
Operation cost at full utilization			
In 1973/74 prices			
Annual maintenance cost*	Rs. 2,381	Rs. 48	Rs. 29
Annual unskilled labor cost**	Rs. 5,475	Rs. 110	Rs. 66
In 1979/80 prices			
Annual maintenance cost	Rs. 3,714	Rs. 75	Rs. 45
Annual unskilled labor cost	Rs. 7,884	Rs. 158	Rs. 95
Construction period[a] including laying of LT lines, etc.	3 years	3 years	3 years
Useful life	30 years of operation	30 years of operation	30 years of operation

[a]Construction period is affected by the period for laying LT lines rather than setting up biogas system. Construction period is assumed to be similar to intensification projects. It is also assumed that generation starts in third year.

Production build up assumed in all cases is 20 percent, 40 percent, 60 percent, 80 percent and 100 percent in first, second, third, fourth, and fifth years of operation respectively.

Costs in 1973/74 prices (A. K. N. Reddy, 1974) have been updated using indexes developed in appendix 2-1.

*Index for maintennce costs assumed to be identical to cosntruction cost index.

**Labor costs calculated by "unskilled labor" component in capital cost index.

Appendix B-3. Determination of Economy of Scale Factor

The following equation was used to obtain capital cost estimates of biogas systems:

$$\text{Capital cost} = k\ (\text{Capacity})^a$$

where a and k could be determined by knowing that the cost of a system of 100 ft^3 capacity was Rs. 3,900 (in 1979/80 prices) and the cost of a system with 5,000 ft^3 capacity was Rs. 63,960 (in 1979/80 prices). Thus,

$$\frac{63,990}{3,900} = \frac{5,000}{100}^{a}$$

that is,

$$\log 16,40 = a \log 50$$

where

$$a = 0.7149, \text{ say } 0.70$$

k can now be determined:

$$k = \frac{63,960}{(5,000)^{0.7}} = 165$$

Appendix B-4.1. Cost of Meeting Electrical Energy Demand from Biogas Systems for Chennapuram

Annual electrical energy consumption	= 12,300 kWh
Gas requirement assuming 25 percent conversion efficiency and average energy content of 0.15 kW/ft^3	= 328,000 ft^3/year or = 898 ft^3/day
Capital cost of 900 ft^3/day = 165 $(900)^{0.7}$	= Rs. 19,295

Cost of generation unit at the rate of Rs. 2,400/kW for connected load is arrived as follows*

Total connected load	= 28 kW
Therefore, cost of generation unit	= Rs. 67,200
Capital cost for provision of LT lines	= Rs. 41,968
Total capital cost	= Rs. 128,263
rounded to	Rs. 128,270

*Connected load per agricultural connection is assumed as 3.7 kW, per domestic is assumed as 0.18 kW, per industrial connection as 3.7 kW for these calculations. Huge savings in capital cost can be obtained by scheduling operation of pump sets, as pump sets are generated for only 5 kW/day.

Discounted capital cost for useful life:

Year 1	Rs. 42,756
Year 2	Rs. 42,756
Year 3	Rs. 42,756

Operating cost (OC):

a. OC for biogas unit	Labor	Rs. 1,422
	Maintenance Cost	Rs. 675
	TOTAL	Rs. 2,097
b. OC for LT lines (at 3% of capital cot of LT lines)		Rs. 1,253
Total OC		Rs. 3,340

Appendix B-4.1. (Cont.)

Year	Capital cost (Rs.)	Operating cost (Rs.)	Units generated
1	42,756	--	--
2	42,756	--	--
3	42,756	3,340	2,460
4	--	3,340	4,920
5	--	3,340	7,380
6	--	3,340	9,840
7	--	3,340	12,300
"	"	"	"
"	"	"	"
32	--	3,340	12,300

P.V. of capital cost	=	Rs. 102,743
P.V. of operation cost	=	Rs. 21,448
Units discounted	=	63,150 kWh
Cost/Unit	=	Rs. 1.96/kWh

Sensitivity to scheduling of pumps such that only 50 percent of pumps are operated simultaneously. Connected load drops down to 17 kW. Capital cost of generation comes down to Rs. 40,800, that is, there is a reduction of Rs. 26,400.

P.V. of capital cost	=	Rs. 81,167
P.V. of operating cost	=	Rs. 21,448
Cost/Unit	=	Rs. 1.62/kWh

Scheduling of pumps to decrease the capacity of generating unit has a significant effect on economics of generating electrical energy through decentralized system.

Appendix B-4.2. Sensitivity of Difference in Cost between Centralized Grid and Decentralized Biogas System to Change in Distance from Central Grid for a Village Similar to Chennapuram in Energy Demand

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One rupee of village investment in HT lines entails the following time profile of outflows:

Year	Capital outflow	Operating outflow
1	0.33	--
2	0.33	--
3	0.34	0.03
4	--	0.03
"	"	"
32	--	0.03

P.V. of capital cost outflow	=	0.7990
P.V. of operating cost outflow	=	0.1926
P.V. of capital and operating costs	=	0.9916
(rounded to)		1.0
Cost of electrical energy cost decentralized system	=	Rs. 1.99
Cost of electrical energy through centralized system	=	Rs. 1.85
Difference in cost	=	Rs. 0.14

Therefore, equivalent HT length in km for neutralizing difference in unit cost.

$$X \times \frac{21900}{50621} \times 1 = 0.11$$

Therefore, $$X = \frac{0.14 \times 50621}{1 \times 21900} = 0.32 \text{ km}$$

Note: Ignoring additional losses due to extra HT lines, extension by 0.32 km to 1.62 km will make both centralized and decentralized systems equally attractive. Beyond 1.62 km decentralized biogas systems for villages similar to Chennapuram in energy demand will be attractive.

Table B-4.3. Sensitivity of Cost of Centralized and Biogas Systems to Increased Energy Demand for Channapuram Village (Rs. unless otherwise indicated)

	Centralized grid			
	Case 1: With increase in connected load		Case 2: Without increase in connected load	
	Energy increase by 50 percent	Energy increase by 100 percent	Energy increase by 50 percent	Energy increase by 100 percent
Present value of capital cost	77,343	92,976	61,710	61,710
Present value of energy cost	28,854	38,472	28,850	38,472
Present value of operations & maintence cost	12,660	12,660	12,660	12,660
Subtotal	118,857	144,108	103,220	112,842
Discounted energy units	75,932 kWh	101,242 kWh	75,932 kWh	101,242 kWh
COST/UNIT	Rs. 1.57/kWh	Rs. 1.42/kWh	Rs. 1.36/kWh	Rs. 1.12/kWh

	Decentralized grid			
	Case 1: With increase in connected load		Case 2: Without increase in connected load	
	Energy increase by 50 percent	Energy increase by 100 percent	Energy increase by 50 percent	Energy increase by 100 percent
New capacity of biogas system (per day)	1,350 ft^3	1,800 ft^3	1,350 ft^3	1,800ft^3
Capital cost[1]	189,080	251,286	129,598	142,368
Yearly operating cost[2]	4,384	5,428	3,849	4,435
Present value of capital cost[3]	151,382	201,627	104,026	110,233
Present value of operating cost[4]	28,142	34,856	28,104	28,216
TOTAL PRESENT VALUE	179,524	236,483	132,130	138,449
Discounted energy units	94,875 kWh	126,500 kWh	94,875 kWh	126,500 kWh
Cost/Unit	Rs. 1.89/kWh	Rs. 1.87/kWh	Rs. 1.39/kWh	Rs. 1.09/kWh
Difference between centralized and decentralized unit cost	Rs. -0.32/kWh	Rs. -0.45/kWh	Rs. -0.03/kWh	Rs. 0.03/kWh
Distance from village distribution point and central grid at which decentralized system becomes attractive	2.5 km	2.3 km	1.48 km	1.39 km

[1]Capital cost includes cost of biogas unit, generation unit, and low tension lines.

[2]Operating cost covers labor and maintenance of low tension lines.

[3]Present value of capital cost computed assuming the construction period is three years, payments are spread out equally, and discount rate is 12 percent.

[4]Present value of operating cost is computed assuming a useful life of thirty years, costs starting in the third year, and a 12 percent discount rate.

Appendix B-5.1. Cost of Meeting Electrical Energy Demand From Biogas System for Satulran

Annual electrical energy consumption		10,560 kWh/year
Gas requirement		281,600 ft^3/year or 772 ft^3/day
Capital cost = $165(772)^{0.7}$		
= Rs. 17,330		
Cost of generation unit for connected load of 10 kW =		Rs. 24,000
Capital cost for LT lines		Rs. 51,756
Total capital cost		Rs. 93,086
O.C. for biogas unit	Labor and maintenance	Rs. 2,063
O.C. for LT lines		Rs. 1,553
	Subtotal	Rs. 3,616
P.V. of capital cost at 12 percent discount rate		Rs. 74,504
P.V. of operating cost		Rs. 23,220
	Total	Rs. 97,724
Discounted energy units		54,302 kWh

Cost/unit = Rs. 1.80/kWh

Reduction in H.T. lines to neutralize cost increase in unit cost:

$$= \frac{0.85 \times 43,464}{1 \times 21,900} = 1.69 \text{ km}$$

That is, beyond 0.4 km of HT line decentralized unit is preferable for a village having similar energy demand.

Appendix B-5.2. Sensitivity of Cost of Centralized Grid and Biogas Systems to Increased Energy Demand for Satulran

Case 1. With increase in connected load

	50% increase in in energy demand	100% increase in in energy demand
Centralized unit		
P.V. of capital cost	Rs. 101,672	Rs. 121,043
P.V. of energy cost	Rs. 24,774	Rs. 33,032
P.V. of O&M cost	Rs. 16,883	Rs. 16,883
	Rs. 143,329	Rs. 170,958
Discounted energy units	65,196 kWh	86,928 kWh
Cost/Unit	Rs. 2.20/kWh	Rs. 1.97/kWh
Decentralized unit		
Biogas system capacity needed	1,158 ft^3/day	1,544 ft^3/day
Capital cost of biogas system		
Capital cost of generation unit	Rs. 36,000	Rs. 48,000
Capital cost of LT lines	Rs. 77,634	Rs. 103,512
	Rs. 136,644	Rs. 179,662
OC for biogas unit:		
Labor and maintenance	Rs. 3,095	Rs. 4,127
OC for LT lines	Rs. 2,330	Rs. 3,106
	Rs. 5,425	Rs. 7,223
P.V. of capital cost	Rs. 109,367	Rs. 143,798
P.V. of operating cost	Rs. 34,811	Rs. 43,413
	Rs. 144,178	Rs. 190,211
Discounted energy units	81,453 kWh	108,604 kWh
Cost per unit	Rs. 1.77/kWh	Rs. 1.75/kWh
Difference for HT lines	Rs. 0.43/kWh	Rs. 0.20/kWh
Difference in terms of HT lines (in km)	1.28 km	1.3 km

Note: Data for case 2 (without increase in load) is not available.

Appendix B-6.1. Cost of Meeting Electrical Energy Demand from Biogas System for Chingapalli

Annual energy consumption	=	9,080 kWh/year
Gas requirement	=	242,133
	or	663 ft^3/day
Capital cost = 165 $(663)^{0.7}$	=	Rs. 15,580
Cost of generation unit for connected load for 20 KW	=	Rs. 48,000
Cost of LT lines	=	Rs. 34,050
Total capital cost	=	Rs. 97,630
Operating cost for biogas system		
Labor and maintenance	=	Rs. 1,772
OC for LT lines	=	Rs. 1,022
		Rs. 2,794
P.V. of capital cost at 12 percent	=	Rs. 78,141
P.V. of operating costs at 12 percent	=	Rs. 17,942
		Rs. 96,083
Discounted energy units	=	46,691 kWh

Cost/unit = Rs. 2.06/kWh

Difference in cost per unit from

Centralized system = Rs. 0.39

Equivalent HT lines in km

$$\frac{0.39 \times 37,369}{1 \times 21,900} = 0.67 \text{ km}$$

That is, beyond 1.1 km decentralized is attractive.

Appendix B-6.2. Sensitivity of Cost of Centralized Grid and Biogas Systems to Increased Energy Demand for Chingapalli

	-- Case 1 -- (increased connected load)		-- Case 2 -- (no increased connected load)	
	a. 50% increase	b. 100% increase	c. 50% increase	d. 100% increase
Centralized unit				
P.V. of capital	76,873	89,617	64,129	64,129
P.V. of energy cost	21,299	28,398	21,299	28,399
P.V. of O&M cost	13,157	13,157	13,157	13,157
	111,329	131,172	98,585	105,685
Discounted energy units	56,054 kWh	74,738 kWh	56,054 kWh	74,759 kWh
Cost/kWh needed yield 12% IRR =	Rs. 1.99/kWh	Rs. 1.76/kWh	Rs. 1.76/kWh	Rs. 1.42/kWh
Decentralized unit				
Capacity of biogas system needed	995 ft^3	1,326 ft^3	995 ft^3	1,326 ft^3
Total capital cost	Rs. 143,755	Rs. 189,420	Rs. 102,730	Rs. 107,370
P.V. of capital cost	Rs. 115,058	Rs. 151,607	Rs. 82,223	Rs. 85,937
P.V. of operating cost	Rs. 26,913	Rs. 35,884	Rs. 23,632	Rs. 29,321
	Rs. 141,971	Rs. 187,491	Rs. 105,855	Rs. 115,258
Discounted energy units	70,037 kWh	93,382 kWh	70,037 kWh	93,382 kWh
Cost per unit	Rs. 2.02/kWh	Rs. 2.00/kWh	Rs. 1.51/kWh	Rs. 1.23/kWh
Difference in costs	Rs. 0.03/kWh	Rs. 0.24/kWh	Rs. 0.25/kWh	Rs. 0.19/kWh
HT lines equivalent length =	1.8 km	2.6 km	1.2 km	1.1 km

Appendix C. Windmill as an Intermediate Solution to Pump Water

1. Windmill (horizontal axis) details

Diameter of wheel	5 meters
Height of tower	20 feet to 30 feet
Weight of steel structures	0.8 tons
Hours of operation per year	10 to 12
Days of operation per day	300
Capital cost: civil (foundation for tower)	Rs. 2,000
Tower cost	Rs. 5,000
Other materials	Rs. 5,000
Total	Rs. 12,000
Equivalent pump capacity	1/2 kW
Useful life	30 years
Wind velocity required (length)	6 km/hour to 35 km/hour
Construction period	
Procurement ordering	2 months
Fabrication	2 weeks
Installation	1 week
Capital recovery factor at 12 percent discount rate	0.124
Capital recovery needed per year to yield 12 percent IRR	Rs. 1,488
Equivalent energy generation per year	0.5 x 11 x 300 = 1650 kWh
Cost per kWh to yield 12 percent IRR	Rs. 0.90

If windmill is used to opeate a pump (without generating electrical energy) the cost of equivalent kWh (that is, the power of the pump is rated at 1/2 kWh) works out ot Re. 0.90 only.

Appendix C. (Cont.)

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2. Windmill (vertical axis, 2.5 kW) Details

Windmill Details (2.5 kW Unit)

Capital cost including unit for windmill	Rs. 20,000	
Generator	Rs. 5,000	
Control module	Rs. 10,000	
Battery storage	Rs. 10,000	
Invertor	Rs. 5,000	
Total capital cost	Rs. 50,000	
Construction period	3 to 6 months	
Energy output per year		
Battery life	2 to 4 years	
Useful life of windmill accessories	30 years	
Number of batteries required	5 to 10	
P.V. of capital cost stream (initial investments plus batteries replacement every 3 years)	Discounted capital cost	44,650
	batteries	23,830
		Rs. 68,540

Discounted energy units
(at 5 hours/day for 300 days)

= 3750 kWh x 8.055

30206 kWh

Capital cost recovery per kWh/generated = Rs. 2.27

Operating cost (1 operator's wages)	Rs. 3,000 to 4,000/year
Operating cost per kWh (approximate)	Rs. 1.00
Cost/kWh to yield 12 percent return on capital employed	Rs. 3.27

Appendix D. Solar System

1. Solar thermal

No firm cost estimates are available. However, an analysis of a development project indicates that a 15 kW power plant is on the order of Rs. 70 lakhs. Probable break-up of expenses is as follows:

Site and building	4%
Control instruments	30%
Energy subsystems	26%
Storage batteries (enough to take of surplus load only)	2%
Conversion subsystems	14%
Biogas auxiliary unit capacity $60m^3$/day (to run motor initially)	2%
Pumps, pipes, and fittings	4%
Fabrication and transport materials	14%
	96%

Energy generated/year (200 sunny days, 5 hours operation per day x 15 kW power) = 15,000 kWh

Capital recovery per kWh assuming useful life is 20 years - $0.134 \times 70 \times 10^5 \div 15 \times 10^3$

$$= \frac{0.134 \times 70 \times 100^5}{15 \times 10^3} = \text{Rs. } 62/\text{kWh}$$

Note: Since the project is of a developmental nature, even the capital recovery per kWh is very high. Including operating cost, the cost/kWh that will yield a 12 percent IRR is as high as Rs. 65.

2. Photovoltaics

The capital cost of a photovoltaic unit works out to around Rs. 8 lakhs and generates on an average 5 kW (7 kW peak) power. the energy content per year that can be generated is 5000 kWh. Capital recovery per kWh needed (assuming 20 years useful life) is:

$$\frac{0.134 \times 8 \times 10^5}{5 \times 10^3} = \text{Rs. } 21/\text{kWh}$$

Appendix E. Availability of Dung--A Survey

Village	Population	Number of households	Cattle & buffaloes	Per capita cattle population	Per household cattle population
1. Mandnur	1,309	276	1,348	1.03	4.88
2. Manchikeni	68	13	41	0.60	3.15
3. Alwad	258	30	122	0.47	4.07
4. Mallakupa	127	18	173	1.36	9.61
5. Mundgod	5,449	1,002	2,058	0.38	2.05
6. Somanahalli	159	38	257	1.62	6.76
7. Kernehosalli	205	31	168	0.82	5.42
Simple average				0.90	5.13
Weighted average				0.55	2.96

Source: "Socioeconomic Impact of Setting up a Hydroelectric Project at Bedthi," R. Venkatesan and coauthors, Administrative Staff College of India (1982).

Estimation of Cattle Population

Village	Population	Household	Cattle and buffaloes	
			Estimate 1	Estimate 2
1. Chingapalli	697	100	627	513
2. Chennapuram	202	50	182	257
3. Satulran	1,205	192	1,085	985

Note: Estimate 1 based on per capita cattle population average calculated above. Estimate 2 based on per household cattle population.

Projected Dung Requirement and Availability

Village	Capacity suggested ft^3/days	Dry dung requirement per day (kg)	Dry dung availability	
			Estimate 1 (kg)	Estimate 2 (kg)
1. Chennapuram	900	135	437	617
	1,350	203		
	1,800	270		
2. Satulran	772	116	2,604	2,364
	1,158	174		
	1,544	232		
3. Chingapalli	663	100	1,505	1,231
	995	149		
	1,326	199		

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