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DIESEL AND ELECTRIC POWERED PUMP IRRIGATION

A Comparative Cost Analysis

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U.S. Agency for International Development

Dacca, Bangladesh

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Introduction

It is expected that power irrigation pump operators will be important users of electricity when made available to rural areas in the future. Currently most irrigation pumps operating in rural Bangladesh are diesel powered.

Conversion from diesel to electric power irrigation and expansion of electric power generation and distribution require heavy investments. An assessment of the comparative costs of diesel and electric powered irrigation is essential to determine the soundness of these investments.

Methodology of Analysis

The method of economic analysis used here is a comparison of costs associated with diesel and electric powered irrigation systems currently operating in Bangladesh. The analysis examines the costs of deep tubewell (Annex A), low lifts pump (Annex B), and shallow tubewell (Annex C) irrigation systems.

The analysis is limited exclusively to the cost side of the equation. Whether diesel powered or electric powered, a particular pump system is assumed to cover the same acreage and crops1/. A comparison of cost effectiveness of the two power sources, therefore only takes into account the cost considerations. The impact of electric versus diesel powered irrigation on pump command area and cropping patterns is left for a separate analysis.

The analysis is conducted from two cost comparison stand points: (1) newly installed diesel powered and electric powered irrigation pumps; and (2) diesel powered pumps and electric powered pumps converted from diesel after a certain time period. Based on the age of the majority

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1/ One benefit of pump electrification might result from the greater reliability and much lower breakdown frequency of an electric pump which may contribute to additional pumping hours. Thus it is reasonable to assume that using electric powered irrigation pumps, more area will be irrigated and agriculture output will increase. On the other hand, the benefit of a diesel pump is its independence of a fixed location. Moreover, stocks of diesel fuel can be stored up, not the case for electric supply where users have no control; if supply of electricity is disrupted, it may be disasterous for crop production. However, these assumptions need field verification for proper analysis.

number of pumps currently in operation, it is assumed that on the average 5 year old deep tubewells and low lift pumps and 2 year old shallow tubewells are converted into electric powered pumps.

The analysis takes into account three cost categories, which vary widely among pumping systems. These categories are:

Investment Costs (Tables A-1, B-1, C-1): All capital costs of diesel and electric powered deep tubewells, low lift pumps and shallow tubewells are identified. Trade and transport cost and overhead cost are added to total capital cost to determine investment cost of each pump type. Salvage values of different equipment are also considered. Investment costs and salvage values are discounted over the life span of pumps, and the salvage values are deducted from investment cost to determine the present value of cost stream of investment costs.

Power Costs (Tables A-2, B-2, C-2): Diesel and electric power costs are calculated based on the assumptions used in the analysis. Fuel and lubricants are priced c.i.f. Chittagong plus trade and transport cost. These prices prevailed in May, 1981. As the world market price of fuel escalates frequently, the reader is cautioned that the power cost of diesel pumps should also be adjusted accordingly. Because of the complexities in calculating the "real" cost of electricity to society, electricity rate recommended by the Rural Electrification Board for irrigation has been used. A sensitivity analysis is also done to show the impact on costs using alternative power rates (Table 4). Power cost is discounted over the life span of the pumps to determine the present value of power cost stream.

Operating and Maintenance Costs (Tables A-2, B-2, C-2): Salary or opportunity costs of labor for operation and protection of pumps, lubricant costs and costs of repair and maintenance are calculated and discounted over the life span of pumps to determine the present value of operation and maintenance cost stream.

Discount Rates: Because some of the above costs, particularly, investment costs, take place at different times depending on the life of equipment, it was necessary to obtain present values of cost expenditures for the purpose of comparison between electric and diesel powered irrigation pumps. Cost streams are expressed in present values applying discounted measures. A real discount rate of 10 percent is assumed, with all monetary values put into "real" terms by deflating and thereby eliminating the element of inflation. As a real rate of return, not a nominal rate bolstered by inflation, 10 percent discount rate is believed to be appropriate.1/

1/ Bangladesh Power Development Board, Tarrif Study, Vol. I, Coopers & Lybrand Associates Limited, November, 1979, Chapter 8, pp 9-11.

The following mathematical formula is used to find the present value of cost streams:

$$C = C_0 + \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - \frac{A_t}{(1+r)^t}$$

where

C_0 = Total investment cost incurred in year 0.

C_t = Cost incurred in year t.

A_t = Salvage value in year t.

n = Life of pump/tubewell.

r = Interest (discount) rate.

Social Costs vs. Private Costs: Finally, the reader should note that this economic analysis is carried out from the point of view of costs incurred by society, not by the private individual. Because duties and taxes imposed by government vary widely among different components of pumps, and because users rent or purchase irrigation pumps at subsidized rates, major conceptual difficulties surround determination of private costs. How the actual costs are shared between the public (government) and private (farmers) sectors of the economy is also not a direct concern of this analysis.

Data for the analysis have been provided by the planners and engineers of the Bangladesh Agricultural Development Corporation (BADC) and the Rural Electrification Board (REB). They are to be thanked for their collaboration.

Summary of Findings

Cost Savings by Pump Type   Table 1 shows that there are significant cost savings from all types of electrified pumps over diesel powered pumps. The highest savings in monetary terms is from deep tubewells followed by low lift pumps and shallow tubewells. In absolute terms, however, this is just the reverse: shallow tubewells followed by low lift pumps and deep tubewells. This is because cost of deep tubewell is about 7 and 11 times higher than low lift pump and shallow tubewell respectively.

Table I: Comparative Savings from Electrified over Diesel Powered Irrigation Pumps 1/

(In Taka)

Type of Pumps	Present Value of Cost Streams		Cost Savings	
	Diesel	Electric	Amount	Percent
Deep Tubewell	470,069	364,201	105,868	23%
Low Lift Pump	114,968	82,684	32,284	28%
Shallow Tubewell	74,638	48,565	26,073	35%

1/ Refer to Tables A-3, B-3 and C-3.

Cost Savings by Type of Cost. Table 2 shows the composition of cost savings from electrified over diesel powered pumps by type of costs. It reveals that in absolute terms, savings in investment costs is highest from deep tubewells followed by low lift pumps and shallow tubewells while in case of savings in power, shallow tubewells rank highest followed by low lift pumps and deep tubewells, and in case of operation cost low lift pumps are followed by shallow tubewells and deep tubewells.

Table 2: Composition of Savings from Electrified over Diesel Powered Irrigation Pumps[1/]

Type of Pumps	Type of Savings: Investment	Power	Operation[2/]	Total
Deep Tubewell	48%	29%	23%	100%
Low Lift Pump	35%	35%	30%	100%
Shallow Tubewell	11%	60%	29%	100%

1/ Refer to Tables A-4, B-4 and C-4.

2/ Includes lubricant, operator's salary, repair and maintenance costs.

Cost Savings from Pump Conversion. Table 3 shows cost savings from converted electric pumps. The highest savings in monetary terms is again from deep tubewells followed by shallow tubewells and low lift pumps, while in absolute terms shallow tubewells rank highest followed by deep tubewells and low lift pumps.

Table 3: Cost Savings from Pump Conversion from Diesel to Electric[1/]

(Amount in Taka)

Type of Pumps	Present Value of Cost Streams		Cost Savings	
	Diesel	Electric	Amount	Percent
Deep Tubewell	470,069	407.999	62,070	13%
Low Lift Pump	114,968	102,984	11,984	10%
Shallow Tubewell	74,638	54,792	19,846	27%

1/ Refer to Tables A-5, B-5, and C-5.

Cost Savings at Alternative Electricity Rates: In the general analysis, Taka 0.70 per KWH electricity rate has been used. This rate is proposed by the Rural Electrification Board (REB) for irrigation and is the existing rate charged by REB. Because this analysis is a social cost analysis, it is necessary to use the real cost of electricity incurred by the nation. However, because in Bangladesh electricity is generated from hydro electric, natural gas and diesel energy, it is difficult, if not impossible, to find the real unit cost of electricity to society. Therefore, the following sensitivity analysis is done to show the impact on savings from electric powered irrigation using alternative power rates. It should be noted that electric line connection to irrigation pumps or "hook-up cost" is assumed to be included in the power rates.

Table 4: An Analysis of Savings from Electric Powered Irrigation at Alternative Power Rates

(Amount in Taka)

Electric Power Rates (Tk./KWH)	Savings over Diesel					
	Deep Tubewell		Low Lift Pump		Shallow Tubewell	
	Amount	%	Amount	%	Amount	%
0.50	143,159	30	43,638	38	30,225	40
0.60	124,514	26	37,961	33	28,149	38
0.70*	105,868	23	32,284	28	26,073	35
0.80	87,222	19	26,607	23	23,997	32
0.90	68,577	15	20,930	18	21,921	29
1.00	49,931	11	15,253	13	19,845	27
1.10	31,285	7	9,576	8	17,768	24
1.20	12,640	3	3,899	3	15,692	21
1.30	(-6,006)	(-1)	(-1,778)	(-2)	13,616	18
1.40	(-24,652)	(-5)	(-7,455)	(-6)	11,540	15
1.50	(-43,297)	(-9)	(-13,132)	(-11)	9,464	13

* Tk.0.70/KWH electricity rate is used in the analysis.

ANNEX A. DEEP TUBEWELL

Assumptions Used In the Analysis

1/ Deep Tubewell depth: 300 ft.

2/ Life span: Life span for different components of a deep tubewell was provided by the BADC engineers.

3/ Purchase cost: All imported items are priced c.i.f. Chittagong while locally produced items are priced "ex-factory".

4/ Gear head is not required when a vertical motor is used.

5/ Field observation shows that for the same pump under same operating conditions electric motors are rated 25 HP (18.7 KW) and diesel engines 30 HP.*

6/ Salvage value: 20% for pump, engine/motor.

7/ In this analysis life of a deep tubewell is considered to be of 20 years. (Economic life of a deep tubewell is considered to be of 20 years by the Planning Division/BADC).

8/ Average pumping hours per year (boro & aus season) = 1000 hours.

9/ Fuel/lubricant oil consumption: According to BADC engineers, 1 gallon of diesel is required for a 30 HP engine to run 1 hour; lubricant @ 0.125 gallon/HP/100 hours running.

10/ Fuel/lubricant oil cost: Fuel and lub oil are priced c.i.f. Chittagong plus trade and transport cost. On this basis price of High Speed Diesel (HSD) is Tk.18.94/Imperial Gallon; price of lub oil (High Viscocity Index) Tk.37.02/I.G. These prices prevailed in May, 1981.

11/ Electric energy consumption: @ 21.9 KWH per operating hour**. Proposed REB electricity rate of Tk. 0.70/KWH is used in the analysis. Comparative costs are also shown in Table 4 at alternative power rates.

12/ The salary or opportunity cost of one man for six months @ Tk.400/month for operation and protection of the equipment.

13/ According to BADC engineers, about 40% of deep tubewells are 8 year old; about 40% are 5 year old, and rest 20% are 1-2 year old. In the analysis it is assumed that on the average, 5 year old diesel powered deep tubewells will be converted to electric powered deep tubewells.

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* Due to lack of maintenance, the output of diesel engine decreases at a faster rate than normal. Therefore engineers recommend over-sized engine.

** $KWH = 0.746 \times HP \times \frac{1}{\text{motor efficiency}}$; assuming 85% efficiency of the motor and the full rated output of the motor is required to drive the pump for equal head and discharge as in the case of diesel driven unit.

Table A-1: Comparative Total Investment Costs of Diesel and Electric Powered Deep Tubewells 3/*

	Investment Cost (in Taka) Diesel	Electric
a. Well components (life: 20 years):		
80 ft. of 14" dia upper well casing @ Tk. 350/rft.	28,000	28,000
100 ft. of 8" dia lower well casing @ Tk.100/rft.	10,000	10,000
120 ft. of 8" dia screen @ Tk.200/rft.	24,000	24,000
Other materials (reducer, centralizer, couplings, bail plug, etc.)	4,000	4,000
b. 2 cusec Turbine pump (life: 15 years)	35,000	35,000
c. Gear head with spicer shaft (life: 20 years) 4/*	10,000	-
d. 30 HP diesel engine (life: 15 years)	50,000	-
e. 3-phase 25 HP vertical electric motor with starter (life: 20 years) 5/*	-	15,000
f. Drilling (to be depreciated in 20 years)	55,000	55,000
g. Pump house construction (life: 20 years)	20,000	20,000
h. Total capital cost	236,000	191,000
i. Trade and transport**	8,050	5,800
j. Overhead	8,000	8,000
k. Total investment cost	252,050	204,800

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* Refer to the assumptions used in the analysis.

** 5% of (a + b + c + d + e).

Table A-2. Cost Items and Salvage Values at Different Times for Diesel and Electric Powered Deep Tubewells

(In Taka)

	Diesel	Electric
Total investment cost	252,050	204,800
20% salvage value of pump and engine in 15th year 6/*	17,000	-
Replacement cost of pump and engine in 16th year	85,000	-
75% salvage value of pump and engine in 20th year	64,000	-
20% salvage value of motor in 20th year	-	3,000
20% salvage value of pump in 15th year 6/*	-	7,000
Replacement cost of pump in 16th year	-	35,000
75% salvage value of pump in 20th year	-	26,000
Annual operation and maintenance costs	25,028	18,530
a. 1000 gallons of High Speed Diesel 9/*	18,940	-
b. 21,900 KWH 11/*	-	15,330
c. Lubricant 9/* (37.5 gallons of lub oil + greasing for diesel; greasing only for electric)	1,688	300
d. Operator and protection 12/*	2,400	2,400
e. Repair and maintenance	2,000	500

* Refer to the assumptions used in the analysis.

Table A-3: Comparative Cost Streams of Diesel and Electric Powered Deep Tubewells Applying Discounted Measures

(In Taka)

	Diesel			Electric		
Year	Capital Items	Operation & Maintenance	Total Costs	Capital Items	Operation & Maintenance	Total Costs
0	252,050	-	252,050	204,800	-	204,800
1-15	-	375,420	375,420	-	277,950	277,950
-	(17,000)[a]	-	(17,000)[a]	(7,000)[a]	-	(7,000)[a]
16	85,000	25,028	110,028	35,000	18,530	53,530
17-20	-	100,112	100,112	-	74,120	74,120
-	(64,000)[a]	-	(64,000)[a]	(29,000)[a]	-	(29,000)[a]

a. Salvage value of pump, engine/motor.

Assuming 10% discount rate, the present value of cost stream for a diesel powered deep tubewell:

$$C_D = \left[252050 + \sum_{t=1}^{15} \frac{25028}{(1+r)^t} + \frac{110028}{(1+r)^{16}} + \sum_{t=17}^{20} \frac{25028}{(1+r)^t}\right] - \left[\frac{17000}{(1+r)^{15}} + \frac{64000}{(1+r)^{20}}\right]$$

$$C_D = [252050 + (25028)(7.605) + (110028)(0.218) + (25028)(0.691)] - [(17000)(0.239) + (64000)(0.149)]$$

$$C_D = 470{,}069$$

Assuming 10% discount rate, the present value of cost stream for an electric powered deep tubewell:

$$C_E = \left[204800 + \sum_{t=1}^{15} \frac{18530}{(1+r)^t} + \frac{53530}{(1+r)^{16}} + \sum_{t=17}^{20} \frac{18530}{(1+r)^t}\right] - \left[\frac{7000}{(1+r)^{15}} + \frac{29000}{(1+r)^{20}}\right]$$

$$C_E = [204800 + (18530)(7.605) + (53530)(0.218) + (18530)(0.691)] - [(7000)(0.239) + (29000)(0.149)]$$

$$C_E = 364{,}201$$

Cost savings over diesel powered deep tubewell:

$C_D - C_E = 105{,}868$ or 23 percent.

Table A-4 Comparative Cost Structures of Diesel and Electric Powered Deep Tubewells

(Amount in Taka)

Cost Items	Present Value of Cost Streams 1/		Cost Savings		
	Diesel	Electric	Amount	Percent	% of Total
Investment	256,981	206,436	50,545	20%	48%
Power	161,255	130,520	30,735	19%	29%
O & M 2/	51,833	27,245	24,588	47%	23%
Total	470,069	364,201	105,868	23%	100%

1/ Formula for calculating present value of investment cost:

$$C_o + \frac{C_t}{(1+r)^t} - \frac{A_t}{(1+r)^t}$$

For power, and O & M cost:

$$\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$$

where

C_o = Investment cost incurred in year 0.

C_t = Cost incurred in year t.

A_t = Salvage value in year t.

n = Life of tubewell.

r = Discount rate (10%)

2/ Includes lubricant, operator's salary, repair and maintenance costs.

Table [illegible] Conversion of a Diesel Powered Deep Tubewell to an Electric Powered Deep Tubewell in the 5th year 13/

(In Taka)

Cost Items and Salvage Values at Different Times	Taka Cost
Investment cost of a diesel powered deep tubewell	252,050
75% salvage value of engine in 5th year	37,500
Cost of a motor in 6th year	15,000
40% salvage value of motor in 20th year	6,000
20% salvage value of pump in 15th year	7,000
Replacement cost of pump in 15th year	35,000
75% salvage value of pump in 20th year	26,000
Annual operation and maintenance cost (see Table A-2):	
a. Diesel powered deep tubewell (Year 1 to 5)	25,028
b. Electric powered deep tubewell (Year 6 to 20)	18,530

Cost Streams

Year	Capital Items	O&M	Total Cost
0	252,050	-	252,050
1 - 5	-	125,140	125,140
-	(37,500)[a]	-	(37,500)[a]
6	15,000	18,530	33,530
7 - 15	-	166,770	166,770
-	(7,000)[a]	-	(7,000)[a]
16	35,000	18,530	53,530
17 - 20	-	74,120	74,120
-	(32,000)[a]	-	(32,000)[a]

a. Salvage value of pump, engine/motor.

* Refer to the assumptions used in the analysis.

(Table A-5 continued)

Assuming 10% discount rate, the present value of cost stream for a converted deep tubewell:

$$C_V = [252050 + \sum_{t=1}^{5} \frac{25028}{(1+r)^t} + \frac{33530}{(1+r)^6} + \sum_{t=7}^{15} \frac{18530}{(1+r)^t} + \frac{53530}{(1+r)^{16}} + \sum_{t=17}^{20} \frac{18530}{(1+r)^t}]$$

$$- [\frac{37500}{(1+r)^5} + \frac{7000}{(1+r)^{15}} + \frac{32000}{(1+r)^{20}}]$$

$$C_V = [252050 + (25028)(3.790) + (33530)(0.564) + (18530)(3.251) + (53530)(0.218) + (18530)(0.691)] - [(37500)(0.621) + (7000)(0.239) + (32000)(0.149)]$$

$$C_V = 407,999$$

Cost savings over diesel powered deep tubewell:

$C_D - C_V = 470,069 - 407,999 = 62,070$ or 13 percent.

(Table A-5 continued)

Assuming 10% discount rate, the present value of cost stream for a converted deep tubewell:

$$C_V = [252050 + \sum_{t=1}^{5} \frac{25028}{(1+r)^t} + \frac{33530}{(1+r)^6} + \sum_{t=7}^{15} \frac{18530}{(1+r)^t} + \frac{53530}{(1+r)^{16}} + \sum_{t=17}^{20} \frac{18530}{(1+r)^t}]$$

$$- [\frac{37500}{(1+r)^5} + \frac{7000}{(1+r)^{15}} + \frac{32000}{(1+r)^{20}}]$$

$$C_V = [252050 + (25028)(3.790) + (33530)(0.564) + (18530)(3.251) + (53530)(0.218) + (18530)(0.691)] - [(37500)(0.621) + (7000)(0.239) + (32000)(0.149)]$$

$$C_V = 407{,}999$$

Cost savings over diesel powered deep tubewell:

$$C_D - C_V = 470{,}069 - 407{,}999 = 62{,}070 \text{ or } 13 \text{ percent.}$$

ANNEX B. LOW LIFT PUMP

Assumptions used in the analysis

1/ Purchase costs: All imported items are priced c.i.f. Chittagong while locally produced items are priced "ex-factory".

2/ Field observation shows that for the same pump under the same operating conditions electric motors are rated 15 HP (11.2 KW) and diesel engines 18 HP.*

3/ Salvage value: 10% of a low lift pump set.

4/ Life of a low lift pump is considered to be of 10 years.

5/ Average pumping hours per year (boro and aus season) = 700 hours.

6/ Fuel/lubricant oil consumption: @ 0.625 gallons of diesel/hour; lubricant @ 0.125 gallon/HP/100 hours running

7/ Fuel/lubricant oil cost: Same as assumption 10 in Deep Tubewell section.

8/ Electric energy consumption: @ 13.2 KWH per operating hour.**

9/ The salary or opportunity cost of one man for six months @ Tk.400/month for operation and protection of pump.

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* Due to lack of maintenance, the output of diesel engine decreases at a faster rate than normal. Therefore engineers recommend over-sized engines.

** $KWH = 0.746 \times HP \times \frac{1}{\text{motor efficiency}}$; assuming 85% efficiency of the motor and the full rated output of the motor is required to drive the pump for equal head and discharge as in the case of diesel driven unit.

Table B-1: Comparative Total Investment Costs of Diesel and Electric Powered Low Lift Pumps 1/*

	Investment Cost (in Taka)	
	Diesel	Electric
a. 2 cusec pump (Life: 10 years)	4,000	4,000
b. Trolley including coupling (Life: 10 years)	3,000	3,000
c. Accessories (Pipes, bends, foot valve, etc.)	8,000	8,000
d. 18 HP diesel engine (Life: 10 years)	20,000	-
e. 15 HP electric motor with starter (Life: 15 years) 2/*	-	10,000
f. Total capital cost	35,000	25,000
g. Trade and transport**	1,750	1,250
h. Overhead	1,000	1,000
i. Total investment cost	37,750	27,250

* Refer to the assumptions used in the analysis.

**5% of capital cost (a + b + c + d + e).

Table B-2: Cost Items and Salvage Values at Different Times for Diesel and Electric Powered Low Lift Pumps.

(In Taka)

	Diesel	Electric
Total investment cost	37,750	27,250
10% salvage value of the pump set in 10th year 3/*	3,500	-
10% salvage value of the pump set (excluding motor) in 10th year.	-	1,500
40% salvage value of motor in 10th year	-	4,000
Annual operation and maintenance costs	12,788	9,368
a. 438 gallons of diesel 6/*	8,296	-
b. 9,240 KWH 8/*	-	6,468
c. Lubricant 6/* (16 gallons of lub oil + greasing for diesel; greasing only for electric)	792	200
d. Operator and protection 9/*	2,400	2,400
e. Repair and maintenance	1,300	300

* Refer to the assumptions used in the analysis.

Table B-2 Comparative Cost Streams of Diesel and Electric Powered Low Lift Pumps Applying Discounted Measures

(In Taka)

	Diesel			Electric		
Year	Capital Items	O&M	Total Costs	Capital Items	O&M	Total Costs
0	37,750	-	37,750	27,250	-	27,250
1-10	-	127,880	127,880	-	93,680	93,680
-	(3,500)[a]	-	(3,500)[a]	(5,500)[a]	-	(5,500)[a]

a. Salvage value of pump set, engine/motor.

Assuming 10% discount rate, the present value of cost stream for a diesel powered low lift pump:

$$C_D = 37750 + \sum_{t=1}^{10} \frac{12788}{(1+r)^t} - \frac{3500}{(1+r)^{10}}$$

$$C_D = [37750 + (12788)(6.144)] - [(3500)(0.386)]$$

$$C_D + 114,968$$

Assuming 10% discount rate, the present value of cost stream for an electric powered low lift pump:

$$C_E = 27250 + \sum_{t=1}^{10} \frac{9368}{(1+r)^t} - \frac{5500}{(1+r)^{10}}$$

$$C_E = [27250 + (9368)(6.144)] - [(5500)(0.386)]$$

$$C_E = 82,684$$

Cost savings over diesel powered low lift pump:

$$C_D - C_E = 32,284 \text{ or } 28 \text{ percent.}$$

Table B-4: Comparative Cost Structures of Diesel and Electric Powered Low Lift Pumps

(Amount in Taka)

Cost Items	Present Value of Cost Streams 1/		Cost Savings		
	Diesel	Electric	Amount	Percent	% of Total
Investment	36,399	25,128	11,271	31%	35%
Power	50,970	39,738	11,232	22%	35%
O&M 2/	27,599	17,818	9,781	35%	30%
Total	114,968	82,684	32,284	28%	100%

1/ Formula for calculating present value of investment cost:

$$C_o - \frac{A_t}{(1+r)^t}$$

For power and O&M cost:

$$\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$$

where

C_o = Investment cost.

A_t = Salvage value in year t.

C_t = Cost incurred in year t.

n = Life of pump.

r = Discount rate (10%).

2/ Includes lubricant, operator's salary, repair and maintenance costs.

Table B-5 Conversion of a Diesel Powered Low Lift Pump to an Electric Powered Low Lift Pump in the 5th Year

(In Taka)

Cost Items and Salvage Values at Different Times	Taka Cost
Investment cost of a diesel powered low lift pump	37,750
60% salvage value of engine in 5th year	12,000
Cost of a motor in 6th year	10,000
75% salvage value of motor in 10th year	7,500
10% salvage value of pump set (excluding motor)	1,500
Annual operation and maintenance cost (see Table B-2):	
a. Diesel powered low lift pump (Year 1-5)	12,788
b. Electric powered low lift pump (Year 6-10)	9,368

Year	Cost Streams: Capital Items	Cost Streams: O&M	Total Cost
0	37,750	-	37,750
1-5	-	63,940	63,940
-	(12,000)[a]	-	(12,000)[a]
6	10,000	9,368	19,368
7-10	-	37,472	37,472
-	(9,000)[a]	-	(9,000)[a]

a. Salvage value of pumpset, engine/motor.

Assuming 10% discount rate, the present value of cost stream for a converted low lift pump:

$$C_V = [37750 + \sum_{t=1}^{5} \frac{12788}{(1+r)^t} + \frac{19368}{(1+r)^6} + \sum_{t=7}^{10} \frac{9368}{(1+r)^t}] - [\frac{12000}{(1+r)^5} \quad \frac{9000}{(1+r)^{10}}]$$

$$C_V = [37750 + (12788)(3.790) + (19368)(0.564) + (9368)(1.790)] - [(12000)(0.621) + (9000)(0.386)]$$

$$C_V = 102,984$$

Cost savings over diesel powered low lift pump:

$$C_D - C_V = 114,968 - 102,984 = 11,984 \text{ or } 10 \text{ percent.}$$

ANNEX C. SHALLOW TUBEWELL

Assumptions Used in the Analysis

1/ Purchase costs: All imported items are priced c.i.f. Chittagong while locally produced items are priced "ex-factory".

2/ Field observation shows that for the same pump under same operating conditions electric motors are rated 4.5 HP (3.4 KW) and diesel engines 6 HP.*

3/ Salvage value: 10% for pump, engine/motor.

4/ Life of a shallow tubewell is considered to be of 15 years.

5/ Average pumping hours per year (boro and aus) = 700 hours.

6/ Fuel/lubricant oil consumption: @ 0.3 gallon of diesel per hour; lubricant @ 0.125 gallon/HP/100 hours running.

7/ Fuel/lubricant oil cost: Same as assumption 10 in Deep Tubewell section.

8/ Electric energy consumption: @ 3.9 KWH per operating hour.**

9/ The salary or opportunity cost of one man for six months @ Tk.200/month for operation and protection of the equipment.

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*Due to lack of maintenance, the output of diesel engine decreases at a faster rate than normal. Therefore engineers recommend over-sized engine.

**$KWH = 0.746 \times HP \times \frac{1}{\text{motor efficiency}}$, assuming 85% efficiency of the motor and the full rated output of the motor is required to drive the pump for equal head and discharge as in the case of diesel driven unit.

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Table C-1 Comparative Total Investment Costs of Diesel and Electric Powered Shallow Tubewells 1/*

	Investment Cost (in Taka)	
	Diesel	Electric
a. Well components (life: 15 years):		
40 ft. of 4" dia strainer	3,700	3,700
100 ft. of 4" dia pipe	4,000	4,000
Other materials (bail plug, hose with nipple, etc.)	1,500	1,500
b. 3/4 cusec pump set (life: 10 years)	4,000	4,000
c. 6 HP diesel engine (life: 10 years)	6,500	-
d. 4.5 HP electric motor with starter 2/* (life: 15 years)	-	5,000
e. Sinking & commissioning	1,500	1,500
f. Total capital cost	21,200	19,700
g. Trade and transport**	985	910
h. Overhead	700	700
i. Total investment cost	22,885	21,310

**Refer to the assumptions used in the analysis.

**5% of (a + b + c + d).

Table C-2. Cost Items and Salvage Values at Different Times for Diesel and Electric Powered Shallow Tubewells.

(In Taka)

	Diesel	Electric
Total investment cost	22,885	21,310
10% salvage value of pump and engine in 10th year 3/*	1,0[illegible]	-
Replacement cost of pump and engine in 11th year	10,500	-
60% salvage value of pump and engine in 15th year	6,300	-
10% salvage value of motor in 15th year	-	500
10% salvage value of pump in 10th year	-	400
Replacement cost of pump in 11th year	-	4,000
60% salvage value of pump in 15th year	-	2,400
Annual operation and maintenance costs	6,573	3,511
a. 210 gallons of High Speed Diesel 6/*	3,977	-
b. 2,730 KWH 8/*	-	1,911
c. Lubricant 6/* (5.3 gallons of lubricant oil + greasing for diesel; greasing only for electric)	296	100
d. Operator and protection 9/*	1,200	1,200
e. Repair and maintenance	1,100	300

* Refer to the assumptions used in the analysis.

Table C-[illegible] Comparative Cost Streams of Diesel and Electric Powered Shallow Tubewells Applying Discounted Measures

(In Taka)

	Diesel			Electric		
Year	Capital Items	O&M	Total Costs	Capital Items	O&M	Total Costs
0	22,885	-	22,885	21,310	-	21,310
1-10	-	65,730	65,730	-	35,110	35,110
-	(1,050)[a]	-	(1,050)[a]	(400)[a]	-	(400)[a]
11	10,500	6,573	17,073	4,000	3,511	7,511
12-15	-	26,292	26,292	-	14,044	14,044
-	(6,300)[a]	-	(6,300)[a]	(2,900)[a]	-	(2,900)[a]

a. Salvage value of pump, engine/motor.

Assuming 10% discount rate, the present value of cost stream for a diesel powered shallow tubewell:

$$C_D = [22885 + \sum_{t=1}^{10} \frac{6573}{(1+r)^t} + \frac{17073}{(1+r)^{11}} + \sum_{t=12}^{15} \frac{6573}{(1+r)^t}] - [\frac{1050}{(1+r)^{10}} + \frac{6300}{(1+r)^{15}}]$$

$$C_D = [22885 + (6573)(6.144) + (17073)(0.350) + (6573)(1.111)] - [(1050)(0.386) + (6300)(0.239)]$$

$$C_D = 74,638$$

Assuming 10% discount rate, the present value of cost stream for an electric powered shallow tubewell:

$$C_E = [21310 + \sum_{t=1}^{10} \frac{3511}{(1+r)^t} + \frac{7511}{(1+r)^{11}} + \sum_{t=12}^{15} \frac{3511}{(1+r)^t}] - [\frac{400}{(1+r)^{10}} + \frac{2900}{(1+r)^{15}}]$$

$$C_E = [21310 + (3511)(6.144) + (7511)(0.350) + (3511)(1.111)] - [(400)(0.386) + (2900)(0.239)]$$

$$C_E = 48,565$$

Cost savings over diesel powered shallow tubewell:

$C_D - C_E$ = 26,073 or 35 percent.

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Table C-4: Comparative Cost Structure of Diesel and Electric Powered Shallow Tubewells

(Amount in Taka)

Cost Items	Present Value of Cost Streams 1/		Cost Savings		
	Diesel	Electric	Amount	Percent	% of Total
Investment	24,649	21,864	2,786	11%	11%
Power	30,246	14,533	15,713	52%	60%
O&M 2/	19,743	12,168	7.575	38%	29%
Total	74,638	48,565	26,073	35%	100%

1/ Formula for calculating present value of investment cost:

$$C_o + \frac{C_t}{(1+r)^t} - \frac{A_t}{(1+r)^t}$$

For power and O&M cost:

$$\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$$

where

C_o = Investment cost incurred in year 0.

C_t = Cost incurred in year t.

A_t = Salvage value in year t.

n = Life of tubewell.

r = Discount rate (10%).

Table C-5. Conversion of a Diesel Powered Shallow Tubewell to an Electric Powered Shallow Tubewell in the 2nd Year

(In Taka)

Cost Items and Salvage Values at Different Times	Taka Cost
Investment cost of diesel powered shallow tubewell	22,885
80% salvage value of engine in 2nd year	5,200
Cost of a motor in 3rd year	5,000
20% salvage value of motor in 15th year	1,000
10% salvage value of pump in 10th year	400
Replacement cost of pump in 11th year	4,000
60% salvage value of pump in 15th year	2,400
Annual operation and maintenance cost (See Table C-2):	
a. Diesel powered shallow tubewell (year 1-2)	6,573
b. Electric powered shallow tubewell (year 3-15)	3,511

Cost Streams

Year	Capital Item	O&M	Total Cost
0	22,885	-	22,885
1-2	-	13,146	13.146
-	(5,200)[a]	-	(5,200)[a]
3	5,000	3,511	8,511
4-10	-	24,577	24,577
-	(400)[a]	-	(400)[a]
11	4,000	3,511	7,511
12-15	-	14,044	14,044
-	(3,400)[a]	-	(3,400)[a]

a. Salvage value of pump, engine/motor.

(Table C-5 continued)

Assuming 10% discount rate, the present value of cost stream for a converted shallow tubewell:

$$C_V = [22885 + \sum_{t=1}^{2} \frac{6573}{(1+r)^t} + \frac{8511}{(1+r)^3} + \sum_{t=4}^{10} \frac{3511}{(1+r)^t}$$

$$+ \frac{7511}{(1+r)^{11}} + \sum_{t=12}^{15} \frac{3511}{(1+r)^t}] - [\frac{5200}{(1+r)^2} + \frac{400}{(1+r)^{10}} + \frac{3400}{(1+r)^{15}}]$$

$$C_V = [22885 + (6573)(1.735) + (8511)(0.751) + (3511)(3.658) + (7511)(0.350) + (3511)(1.111)] - [(5200)(0.826) + (400)(0.386) + (3400)(0.239)]$$

C_V = 54,792

Cost savings over diesel powered shallow tubewell:

$C_D - C_V$ = 74,638 - 54,792 = 19,846 or 27 percent.

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