Prospect of solar irrigation system over conventional irrigation system.

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Abstract:

Bangladesh is a third world country with less economic growth. About 36% (Rahimafrooz) of GDP and 64% (Rahimafrooz)of its employment comes from agriculture. But our agricultural history is declining due to lack of irrigation facility .At the same time the existing irrigation facilities cost the government a huge amount of subsidy every year. So it's a high time that we find an alternative way of irrigation so that our subsidy is reduced as well as people get water throughout the year. And gives birth to our project. In our project, we will be analyzing the feasibility of solar irrigation system for surface irrigation in the context of Bangladesh. Our main goal is to identify if the existing diesel run STW can be replaced by solar irrigation pump or not. RETScreen software has been used for the analysis.

Introduction:

Bangladesh is a agricultural country with its 36 % GDP based on agriculture.64% of employment is due to this reason. The national demand of electricity is 5000 MW but production available is3500 MW. Among the people only 35% has access to electricity and only 13.5% (760 MW) is used as irrigational electricity.

The irrigation system of Bangladesh comprises of three types of pumps ,namely-

1. Shallow Tube Well (STW)
2. Deep Tube Well (DTW)
3. Low Lift Pump (LLP)

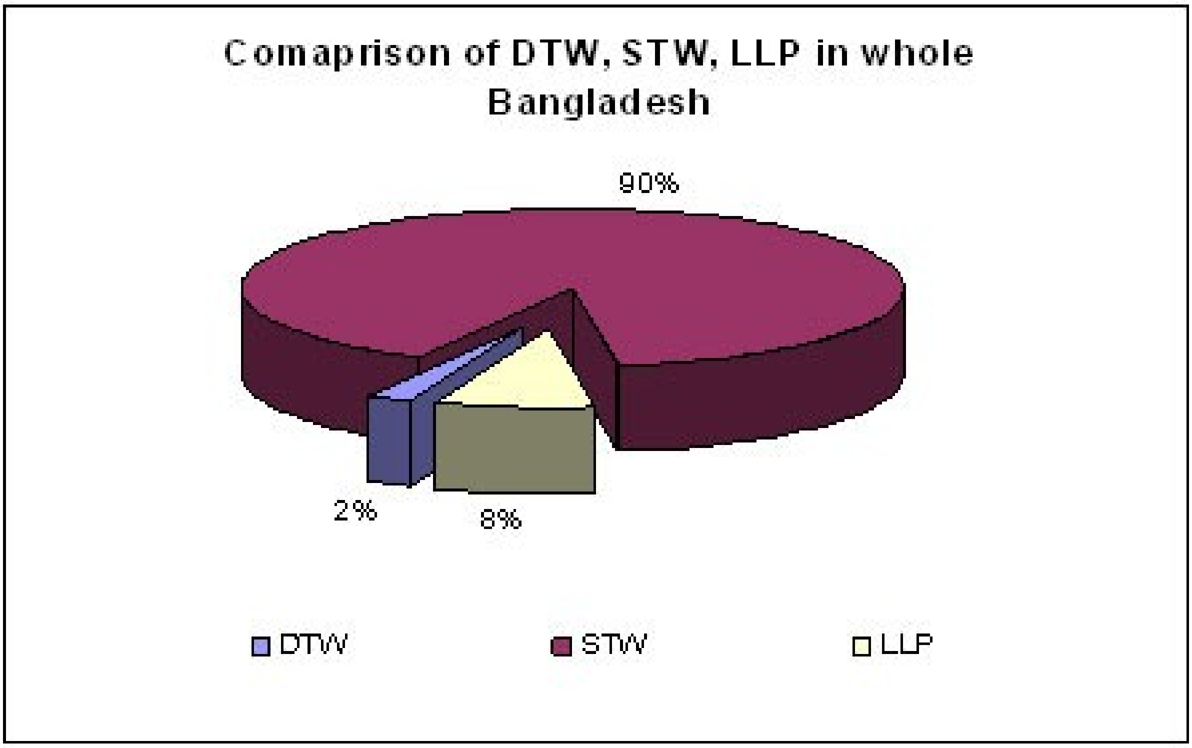
A brief description of Bangladesh Irrigation System is tabulated in chart

Organization Wise Summary of Irrigation Equipment Used, Area Irrigated and Benefited Farmers: 2010-11

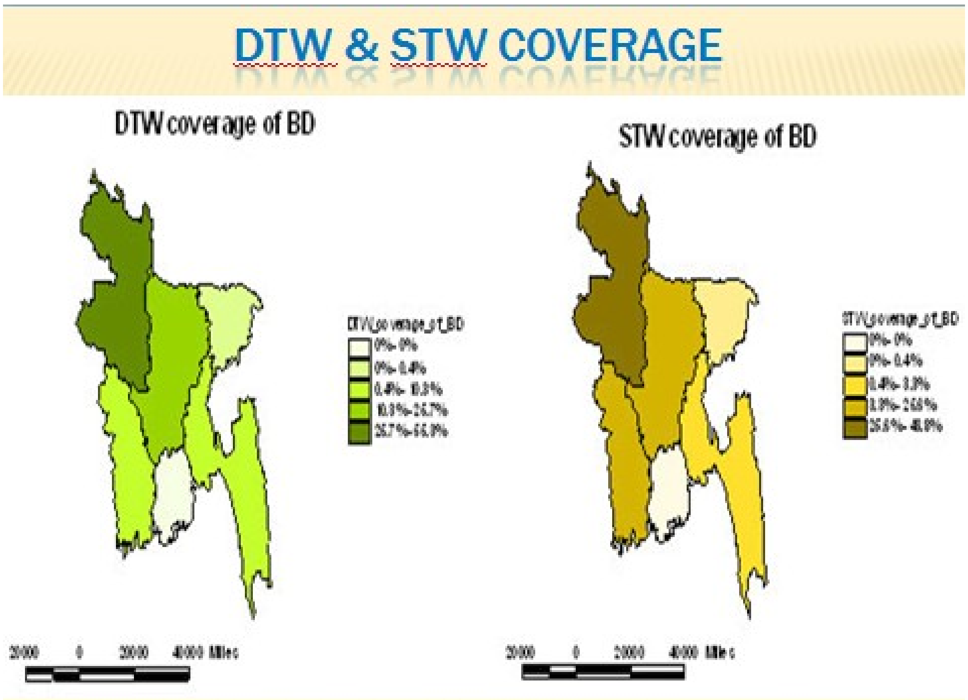
Type of Equipment	Name of organization	Operated by Electricity					Operated by Diesel			Total		
		Unit			Irrigated Area(hec.)	No of Farmers	Unit	Irrigated Area(hec.)	No of Farmers	Unit	Irrigated Area(hec.)	No of Farmers
		PDB	REB	TOTAL								
DTW	BADC	885	11298	12183	297708	821906	1647	36615	91560	13830	334323	913466
	BMDA	770	12041	12811	285189	706278	11	247	567	12822	285436	706845
	Others	476	5215	5691	83486	446978	1327	15961	73101	7018	99447	520079
	Total	2131	28554	30685	666383	1975162	2985	52823	165228	33670	719206	2140390
STW	BADC	8	42	50	155	530	88	260	890	138	415	1420
	BMDA	0	0	0	0	0	0	0	0	0	0	0
	Others	21291	206367	227658	531231	2348413	1321353	2973641	8164262	1549011	3504872	10512675
	Total	21299	206409	227708	531386	2348943	1321441	2973901	8165152	1549149	3505287	10514095
LLP	BADC	117	664	781	31613	76274	3232	35729	97067	4013	67342	173341
	BMDA	10	15	25	836	1394	0	0	0	25	836	1394
	Others	1277	8232	9509	59431	415694	160122	882372	1985425	169631	941803	2401119
	Total	1404	8911	10315	91880	493362	163354	918101	2082492	173669	1009981	2575654
DTW +STW +LLP		24834	243874	268708	1083573	4817467	1487780	4046689	10412872	1756488	5234474	15230339
Manual & Artesian Well		0	0	0	0	0	0	0	0	0	6381	3191
Traditional Method		0	0	0	0	0	0	0	0	0	3814	4504
Gravity Flow		0	0	0	0	0	0	0	0	0	19071	25235
COUNTRY TOTAL		24834	243874	268708	1083573	4817467	1487780	4046689	10412872	1756488	5263740	15263269

Table 1

From the above chart it is easily describable that 90 % of the pumps are STW type and this ratio can be shown as-



The pie chart above distinguishes the methods of irrigation in Bangladesh. The STW leads the table. The coverage of STW and DTW are shown in the next figure1, which resembles a Bangladesh map.



It is also found that about 85% of these STW are diesel run and this causes the government to use a large portion of its irrigation budget to be spent on subsidy only.

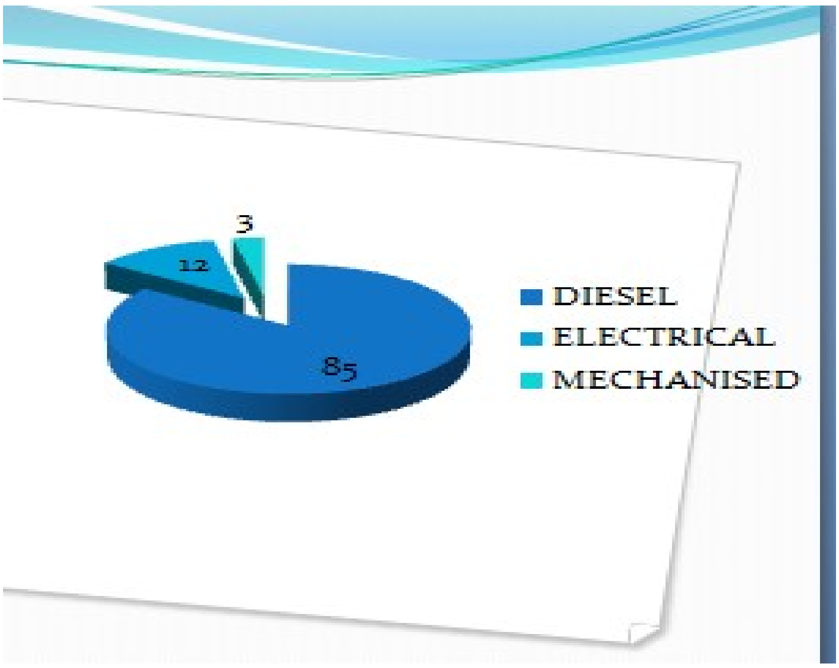


FIG: PUMP OPERATION

So, our main focus is to replace these STW (90% of pump), with solar irrigation pump and thus to reduce the subsidy and thus ultimately reducing the irrigation cost of farmer.

Prospect of solar irrigation in Bangladesh:

Bangladesh is located in the Tropical region bestowed with direct solar insulation .This fact comprises the possibility that solar irrigation system should be practical and feasible in Bangladesh. The NASA provides us with the data below in chart

MONTH	Solar radiation (Wh/m2	
	NASA	RECORDED
JAN	4.32	3.96
FEB	5.25	4.47
MARCH	5.95	5.88
APRIL	6.33	6.24
MAY	5.74	6.17
JUNE	5.04	5.25
JULY	4.41	4.79
AUG	4.36	5.16
SEP	4.03	4.96
OCT	4.42	4.88
NOV	4.46	4.42
DEC	4.21	3.82

Table 2

This can also be shown as below in figure 2

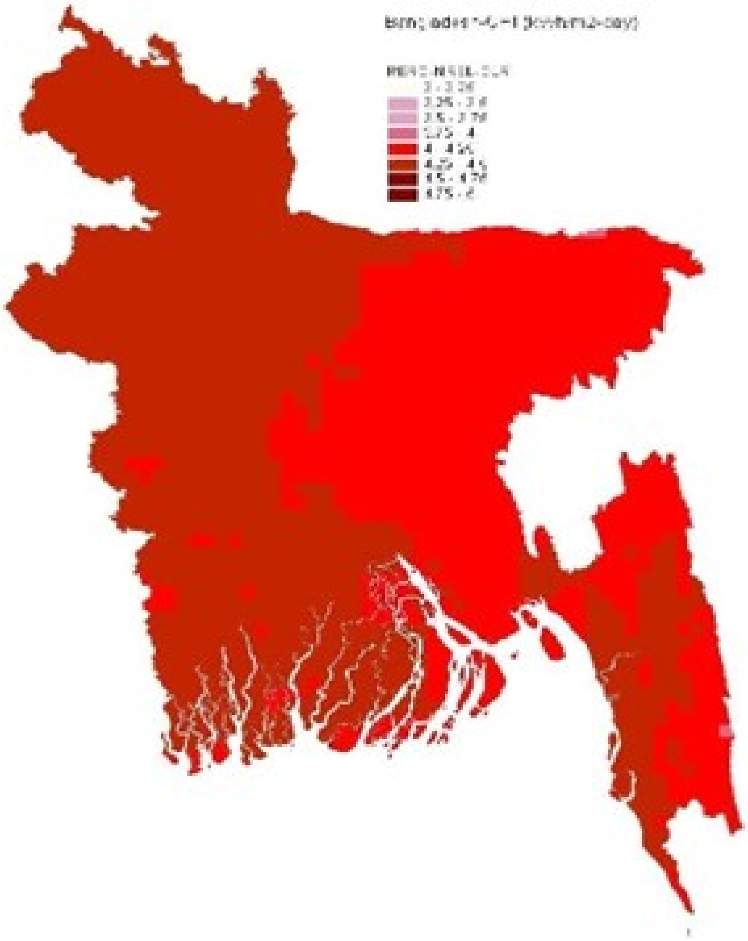


Fig 2: Global Horizontal Irradiance map of Renewable Energy Research Centre (RERC)-National Renewable Energy Laboratory (NREL) - *German* Aerospace Center (*DLR*) showing averaged NREL and DLR maps tuned to Dhaka

FIG : 2

As it’s not feasible to carry our experiment throughout Bangladesh, we will select an area and thus collect sufficient data for that region and carry out our experiment. In this case we have taken BARI, Gajipur as our target area.

The Practical Data:

The data were collected from BARI. A typical August morning was chosen and the data were collected.

We used a pump, solar panels, flow meter to record data for surface irrigation. The specification is listed below-

Pump:	Solar Panel:
Brand –honewell	Brand-Tata
RPM-1900	Nos-4
Capacity-0.5hp	Capacity-75 w/panel

Head:

Suction head: 1.1 m

Discharge head: 0.8m

Drawdown head: 0.2 m

The figure :3,4,5,6 shows the experimental set up in the next page

Figure 3

<u>Figure 4</u>

Figure 5

Figure 6

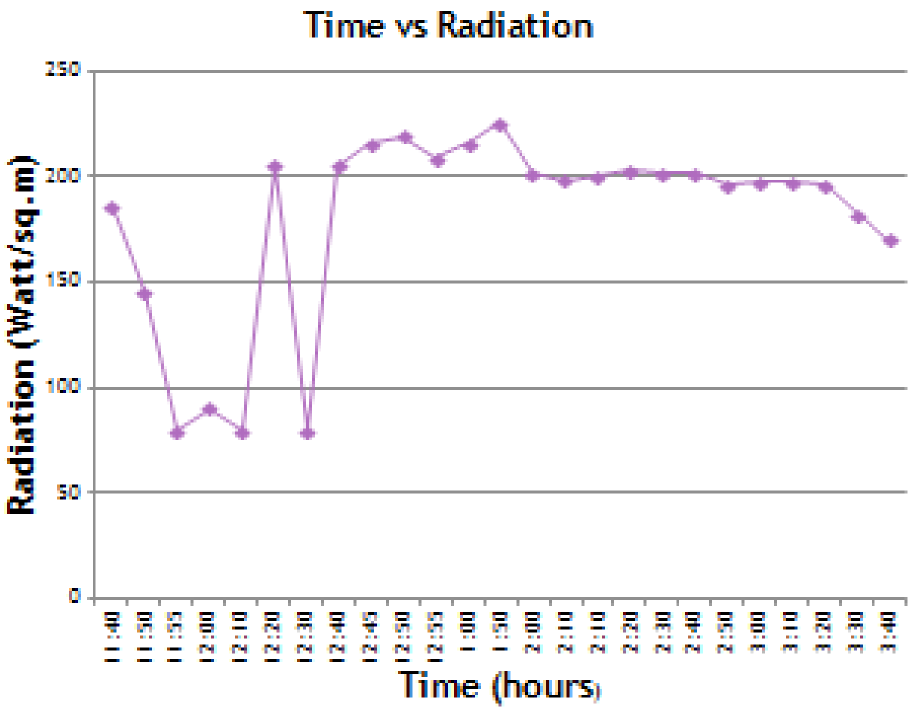
The recorded data are tabulated in chart

Time(hrs)	Radiation (W/sq m)	Time taken to discharge 100 litre of water(sec)	Flow rate (L/s)	Discharge (m3) Initially- 73.06 m3
11:30	239	42.7	2.34	
11:40	186	67	1.49	
11:50	145	120	0.83	
11:55	80	134	0.75	
12:00	84	100	1	
12:10	80	132	0.757	
12:20	210	43	2.325	
12:30	79	142	0.7	
12:40	205	42	2.39	
12:45	218	41	0.46	
12:50	209	43	2.325	
Cont...				
12:55	209	46	2.174	
1:00	215	44	2.27	
1:50	225	41	2.44	
2:00	202	44.5	2.24	
2:10	198	44.3	2.257	
2:20	200	46	2.174	
2:30	203	46.	2.174	
2:40	202	46.5	2.15	
2:50	202	46	2.174	
3:00	197	50	2	
3:10	197	50	2	

Cont...				
12:55	209	46	2.174	
1:00	215	44	2.27	
1:50	225	41	2.44	
2:00	202	44.5	2.24	
2:10	198	44.3	2.257	
2:20	200	46	2.174	
2:30	203	46.	2.174	
2:40	202	46.5	2.15	
2:50	202	46	2.174	
3:00	197	50	2	
3:10	197	50	2	
3:20	196	52	1.9	
3:30	182	57.5	1.74	95.1

Table 3

The graphical representation is shown in figure


Time vs Radiation
Radiation (Watt/sq.m)
250
200
150
100
50
0
11:40
11:50
11:55
12:00
12:10
12:20
12:30
12:40
12:45
12:50
12:55
1:00
1:50
2:00
2:10
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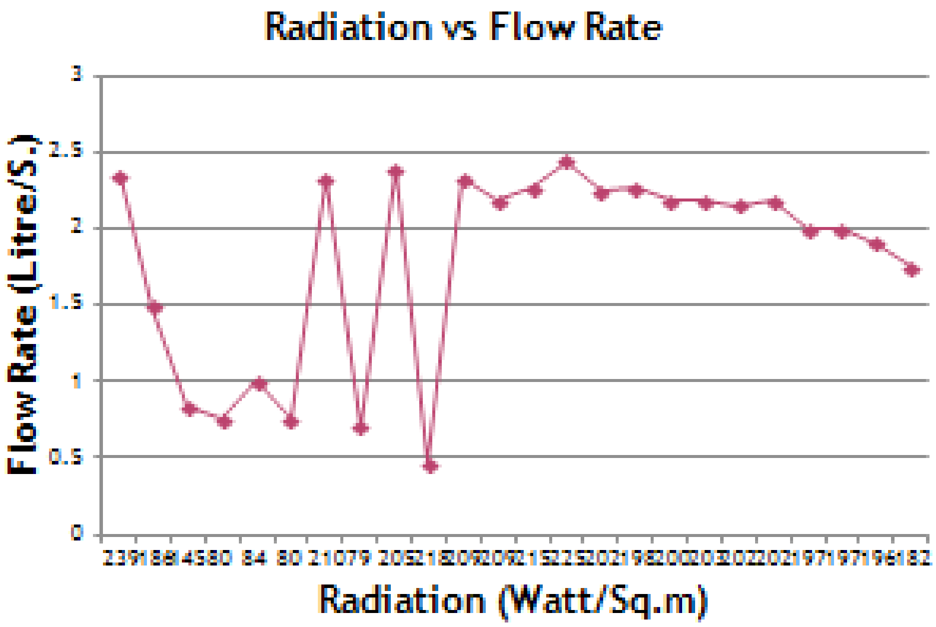
2:20
2:30
2:40
2:50
3:00
3:10
3:20
3:30
3:40
Time (hours)


Radiation vs Flow Rate
Flow Rate (Litre/S.)
3
2.5
2
1.5
1
0.5
0
Radiation (Watt/Sq.m)

Experiment results:

From graphs, we can see that the solar radiation fluctuates till 1:00 pm but after that it maintains a steady value. This may be due to the cloudy forecast that we had on that day.

In respond to the radiation fluctuation, the flow rate also fluctuates till 1:00 pm, and after that it maintains a steady balance value

Practically there was no water pumping below 18 watt/sqm. So the critical radiation is 18 watt/sqm .

Our next step is to put this practical data to RETScreen software to analyze the result for the project to be viable.

Software Analysis

The entire project has been simulated through RETScreen Renewable Energy Software. This software is used to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs).It follows five steps to evaluate any project. The steps are

1. Start
2. Energy model
3. Cost Analysis
4. Emission Analysis
5. Financial Analysis

6. Sensibility and Risk Analysis

To evaluate my project ,I followed the above mentioned steps using the data obtained during our observation of the project at BARI.

Start:

This part of the software describes the project name, location, method of analysis. I have used the method 2 procedure as this gives more accurate result.

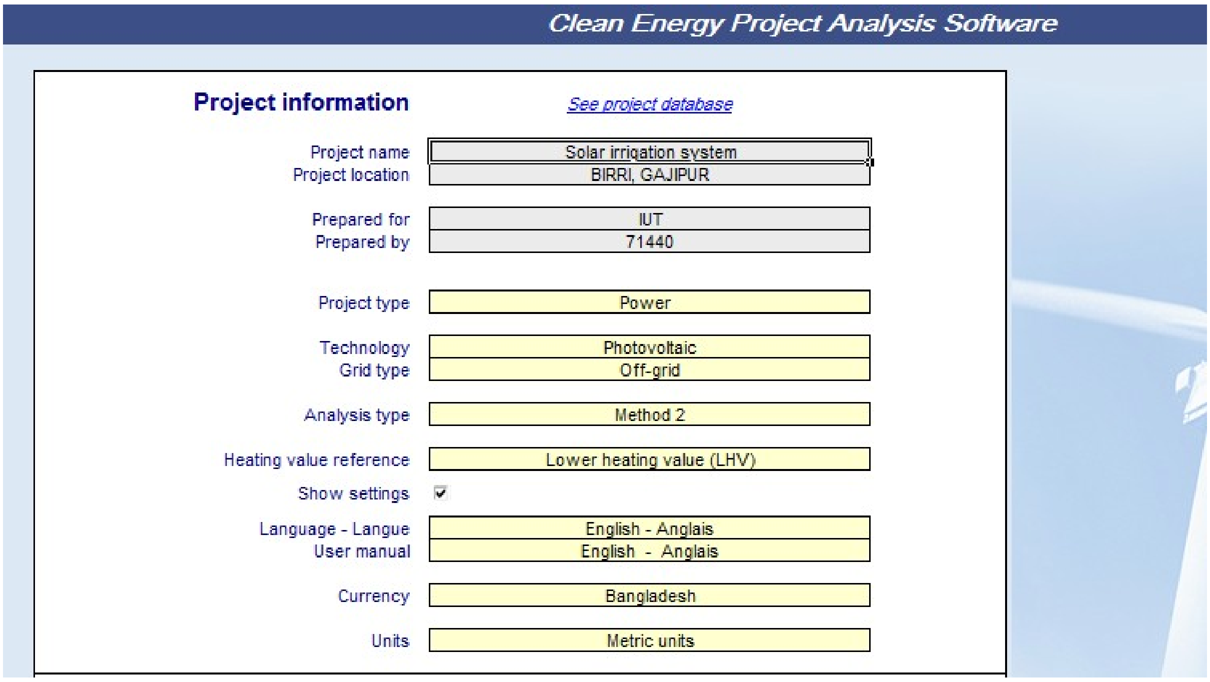


Table 4

All currency is mentioned in Taka for better understanding of the project viability. I preferred off grid technology as our system was not connected to any external grid..

Water Pumping:

My priority is to satisfy the irrigation need during the month of BORRO, as it is mostly grown in Bangladesh and needs to be planted during Nov-Dec. And there is scarcity of ground water during this time of the year. The pump parameters are calculated from the data. From chart we find that our pump

delivers 22.04 m3of water

We require 11500 m3hectare of water for BORO[1].So ,if we assume to run

our pump 8 hours a day and for two and half months (75 days) then we need to

pump 146 m3of water daily.Our experiment pump drives only 22.04 m3of

water in 3hours and 20 minutes.So we can pump 53m3of water in 8 hours

,which is sufficient for only 0.363 hectares of land .This data has been provided to the RETScreen and it thus gives us output as to how much daily and annual electricity will be needed for irrigating 0.363 hectares of land. The output provided is 1.56 kwh of electricity .This output is then used in the Energy model of the software.

Water pumping

Load characteristics

○ Method 1
⊙ Method 2

Description	Application	Unit	Quantity	Daily water use per unit		Base case: Daily water use	Proposed case: Water use reduction	Proposed case: Daily water use
						m^3/d	%	m^3/d
Rice field	Irrigation	ha	0.363	$m^3/d/ha$	146	53.00	0%	53.00

		Base case	Proposed case
Daily water use	m^3/d	53.00	53.00
Suction head	m	1.1	1.1
Drawdown	m	0.2	0.2
Discharge head	m	0.8	0.8
Pressure head	m	0.0	0.0
Friction losses	%	3%	3%
Total head	m	2.1	2.2
Mechanical energy - daily	kWh	0.30	0.31
Mechanical energy - annual	kWh	109.1	114.0

Pump & motor

		Base case	Proposed case
Description		centrifugal	centrifugal
Type		DC	DC
Efficiency	%	20%	20%

Summary

		Base case	Proposed case
Electricity - daily	kWh	1.49	1.56
Electricity - annual	kWh	545.66	570.09

Table 5

Energy model:

In this portion ,I highlighted on the load that our system has to provide.The only load is a 0.3 KW centrifugal pump. Both loads for the proposed case(solar irrigation) and the Base case(diesel engine irrigation) are assumed to be same .

I used Tk 61 as the current diesel price in Bangladesh which gives me Base case load DC load to be 60.8 watt .It is shown in Figure7 also used as the heating

value as 13000kjkwh from the Figure.

RETScreen Energy Model - Power project

Power project

Base case power system

Grid type		Off-grid
Technology		Reciprocating engine
Fuel type		Diesel (#2 oil) - L
Fuel rate	BDT/L	61.000
Capacity	kW	
Heat rate	kJ/kWh	13,000
Annual O&M cost	BDT	0
Electricity rate - base case	BDT/kWh	21.854
Total electricity cost	BDT	3,962

Load characteristics

○ Method 1
⦿ Method 2

Description	AC/DC	Intermittent resource-load correlation	Base case load W	Hours of use per day h/d	Days of use per week d/w	Proposed case load reduction %	Proposed case usage time reduction %
pump	DC	Positive	62.08	8.00	7	0%	0%

Table 6

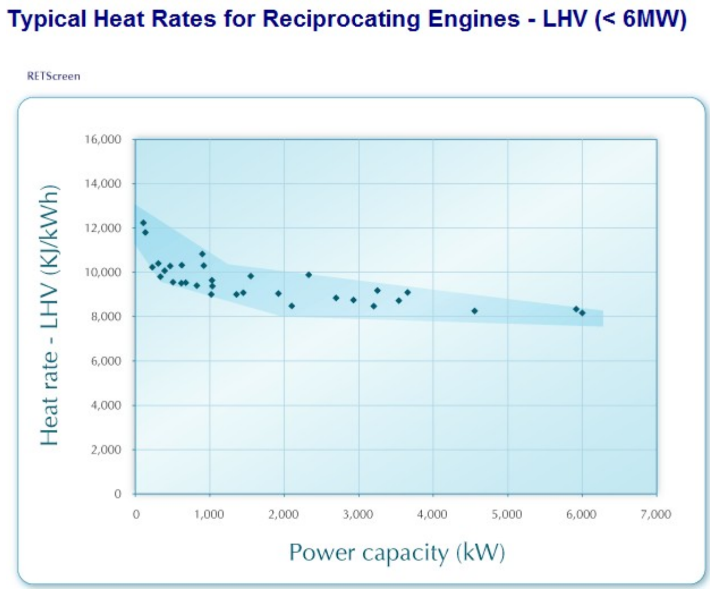


Figure 7

For the proposed case I took the daily radiation data from the NASA meteorological center for Gazipur(24.8 N,90.4 E).It is shown

Proposed case power system

Inverter			
Capacity	kW	0.0	Peak load - annual - AC
Battery			
Days of autonomy	d	0.0	
Technology		Photovoltaic	
Resource assessment			
Solar tracking mode		Fixed	
Slope	°	25.0	
Azimuth	°	0.0	

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity delivered to load MWh
January	4.37	5.74	0.02
February	5.08	6.11	0.01
March	5.81	6.31	0.02
April	5.86	5.78	0.01
May	5.19	4.84	0.02
June	4.47	4.10	0.01
July	4.12	3.83	0.02
August	4.11	3.96	0.02
September	3.82	3.89	0.01
October	4.31	4.87	0.02
November	4.38	5.58	0.01
December	4.19	5.67	0.02
Annual	**4.64**	**5.05**	**0.18**

Annual solar radiation - horizontal	MWh/m²	1.69
Annual solar radiation - tilted	MWh/m²	1.84

Table 7

The experiment set up has 4 -75 watt si-monocrystalline solar panel with an efficiency of approx 16% [2].No battery is used as no energy is stored and no inverter is used as we are using a DC pump. The RETScreen shows the below data

Photovoltaic			
Type		mono-Si	
Power capacity	kW	0.30	
Manufacturer		TATA	
Model			
Efficiency	%	16.0%	
Nominal operating cell temperature	°C	45	
Temperature coefficient	% / °C	0.40%	
Solar collector area	m²	1.9	
Control method		Maximum power point tracker	
Miscellaneous losses	%	0.0%	
Summary			
Capacity factor	%	19.4%	
Electricity delivered to load	MWh	0.18	100.0%

Cost Analysis:

In this portion RETScreen deals with the costing of the project by identifying the initial cost, maintenance cost, fuel cost etc. Our project encounters costs like solar panel cost(100tk for 1watt),pump and motor cost(25000tk),boring cost(50tk for 20ft),transportation cost (1000tk),engineering cost(5000tk),collector support structure(2000tk) and contingencies of 10%. The contingency allowance should be included to account for unforeseen annual expenses and will depend on the level of accuracy of the operation and maintenance cost estimate section. It typically ranges from 10 to 20% of these costs. We have taken 10%of contingency. The cost analysis is shown in figure

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Feasibility study	cost	0	BDT -	BDT -	
Subtotal:				**BDT -**	0.0%
Development					
Development	cost	0	BDT -	BDT -	
Subtotal:				**BDT -**	0.0%
Engineering					
Engineering	cost	1	BDT 5,000	BDT 5,000	
Subtotal:				**BDT 5,000**	7.2%
Power system					
Photovoltaic	kW	0.30	BDT 100,000	BDT 30,000	
Road construction	km	0		BDT -	
Transmission line	km	0		BDT -	
Substation	project	0		BDT -	
Energy efficiency measures	project	0		BDT -	
Collector support structure	cost	1	BDT 2,000	BDT 2,000	
				BDT -	
Subtotal:				**BDT 32,000**	46.2%
Balance of system & miscellaneous					
Spare parts	%	0.0%		BDT -	
Transportation	project	1	BDT 1,000	BDT 1,000	
Training & commissioning	p-d			BDT -	
pump,motor,pipe line	cost	1	BDT 25,000	BDT 25,000	
Contingencies	%	10.0%	BDT 63,000	BDT 6,300	
Interest during construction	0.00%	0 month(s)	BDT 69,300	BDT -	
Subtotal:				**BDT 32,300**	46.6%
Total initial costs				**BDT 69,300**	100.0%

Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M				
Parts & labour	project	1	BDT 200	BDT 200
boring	cost	1	BDT 50	BDT 50
Contingencies	%		BDT 250	BDT -
Subtotal:				**BDT 250**

Annual savings	Unit	Quantity	Unit cost	Amount
Fuel cost - base case				
Diesel (#2 oil)	L	65	BDT 61.000	BDT 3,962
Subtotal:				**BDT 3,962**

Periodic costs (credits)	Unit	Year	Unit cost	Amount
pump (overhaul)	cost	5	BDT 500	BDT 500
				BDT -
End of project life	credit			BDT -

Table 8

As part of the RETScreen Clean Energy Project Analysis Software, an Emission Analysis worksheet is provided to estimate the greenhouse gas emission reduction (mitigation) potential of the proposed project. It also provides GHG global warming potential factors. The Base case electricity system and Base case system GHG summary sections provide a description of the emission profile of the baseline system. The Proposed case system GHG summary section provides a description of the emission profile of the proposed project. The GHG emission reduction summary section provides a summary of the estimated GHG emission reduction based on the data entered by the user in the preceding sections. Results are calculated as equivalent tones of CO2 avoided per annum.

The emission reduction of our project is shown in figure

RETScreen Emission Reduction Analysis - Power project

Emission Analysis

- ○ Method 1
- ◉ Method 2
- ○ Method 3

Global warming potential of GHG

25 tonnes CO2 = 1 tonne CH4 (IPCC 2007)

298 tonnes CO2 = 1 tonne N2O (IPCC 2007)

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	emission factor kg/GJ	CH4 emission factor kg/GJ	N2O emission factor kg/GJ	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Diesel (#2 oil)	100.0%	73.3	0.0020	0.0020	1	0.266	0.2
Total	100.0%	73.3	0.0020	0.0020	1	0.266	0.2

Proposed case system GHG summary (Power project)

Fuel type	Fuel mix %	emission factor kg/GJ	CH4 emission factor kg/GJ	N2O emission factor kg/GJ	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Solar	100.0%	0.0	0.0000	0.0000	0	0.000	0.0
Total	100.0%	0.0	0.0000	0.0000	0	0.000	0.0

Table 9

As we see, our project reduces carbon di oxide use by 0.2 ton. It also resembles this statistics as other parameter. Reducing carbon- di- oxide use by 0.2 tones resembles 85.9 liters of gasoline not being consumed.

GHG emission reduction summary						
	Base case GHG emission tCO2	Proposed case GHG emission tCO2		Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Power project	0.2	0.0		0.2		0.2

Net annual GHG emission reduction	0.2	tCO2	is equivalent to	85.9	Litres of gasoline not consumed

Table 10

Financial Analysis:

One of the primary benefits of using the RETScreen software is that it facilitates the project evaluation process for decision-makers. The *Financial Analysis* worksheet, with its financial parameters input items (e.g. discount rate, debt ratio, etc.), and its calculated financial viability output items (e.g. IRR, simple payback, NPV, etc.), allows the project decision-maker to consider various financial parameters with relative ease.

In our project, we have taken the inflation rate as 10.7 (World Bank 2012),fuel escalation rate as 6%.We have also taken the project life to be 20 years. The total project being financed by the owner itself so no grant or subsidy is taken into account. The annual income which considered is only that of GHG reduction ..

RETScreen Financial Analysis - Power project

Financial parameters		
General		
Fuel cost escalation rate	%	6.0%
Inflation rate	%	10.7%
Discount rate	%	0.0%
Project life	yr	20
Finance		
Incentives and grants	BDT	0
Debt ratio	%	

Table 11

Many of the summary items here are calculated and/or entered in the *Cost Analysis* worksheet and transferred to the *Financial Analysis* worksheet. The remainder are calculated and/or entered in other parts of the *Financial Analysis* worksheet.

The total initial costs represent the total incremental investment that must be made to bring the proposed case project on line, before it begins to generate savings and/or income. The total initial costs are the sum of the estimated feasibility study, development, engineering, power system.

The total annual costs are calculated by the model and represent the yearly costs incurred to operate, maintain and finance the project. It is the sum of the O&M, fuel cost for the proposed case system and debt payments

The periodic costs and periodic credits are entered by the user in the *Cost Analysis* worksheet and are transferred here. The model escalates the periodic costs and credits yearly according to the inflation rate starting from year 1 and throughout the project life.

Project costs and savings/income summary			
Initial costs			
Engineering	7.2%	BDT	5,000
Power system	46.2%	BDT	32,000
Balance of system & misc.	46.6%	BDT	32,300
Total initial costs	**100.0%**	**BDT**	**69,300**
Annual costs and debt payments			
O&M		BDT	250
Fuel cost - proposed case		BDT	0
Total annual costs		**BDT**	**250**
Periodic costs (credits)			
pump (overhaul) - 5 yrs		BDT	500
Annual savings and income			
Fuel cost - base case		BDT	3,962
Total annual savings and income		**BDT**	**3,962**

Table 12

The results from the financial viability portion provide the decision-maker with various financial indicators for the proposed case project.

The model calculates the pre-tax internal rate of return (IRR) on equity (%), which represents the true interest yield provided by the project equity over its life before income tax. If the internal rate of return is equal to or greater than the required rate of return of the organization, then the project will likely be considered financially acceptable (assuming equal risk). If it is less than the required rate of return, the project is typically rejected

Financial viability		
Pre-tax IRR - equity	%	5.7%
Pre-tax IRR - assets	%	5.7%
After-tax IRR - equity	%	5.7%
After-tax IRR - assets	%	5.7%
Simple payback	yr	18.7
Equity payback	yr	12.9
Net Present Value (NPV)	BDT	59,674
Annual life cycle savings	BDT/yr	2,984
Benefit-Cost (B-C) ratio		1.86
GHG reduction cost	BDT/tCO2	(17,113)

Table 13

The model calculates the simple payback (year), which represents the length of time that it takes for a proposed project to recoup its own initial cost, out of the income or savings it generates. The simple payback method is not a measure of how profitable one project is compared to another. Rather, it is a measure of time in the sense that it indicates how many years are required to recover the investment for one project compared to another

The model calculates the Net Present Value (NPV) of the project, which is the value of all future cash flows, discounted at the discount rate, in today's currency. The difference between the present values of these cash flows, called the NPV, determines whether or not the project is generally a financially acceptable investment. Positive NPV values are an indicator of a potentially feasible project

The model calculates the net Benefit-Cost (B-C) ratio, which is the ratio of the net benefits to costs of the project. Net benefits represent the present value of annual income and savings less annual costs, while the cost is defined as the project equity. Ratios greater than 1 are indicative of profitable projects.

The model calculates the GHG reduction cost. The GHG reduction cost is calculated by dividing the annual life cycle savings of the project by the net GHG reduction per year, averaged over the project life.

The total annual savings and income represents the annual savings and/or income realized due to the implementation of the proposed case system.

The model calculates the annual GHG reduction income, which represents the income generated by the sale or exchange of the GHG reduction. This value is calculated from the annual net GHG reduction and the GHG reduction credit rate. The yearly value of GHG reduction income is escalated at the GHG reduction credit escalation rate.

Annual income		
Electricity export income		
GHG reduction income	☐	
Net GHG reduction	tCO_2/yr	0
Net GHG reduction - 20 yrs	tCO_2	3

The software also provides us with the yearly cash flow .Thus showing us the positive cash flow and the year it takes to attain that. For our project, the positive cash flow occurs at the 13th year and after 20 years of the project the project will generate about 59674 Tk.

Yearly cash flows			
Year	Pre-tax	After-tax	Cumulative
#	BDT	BDT	BDT
0	-69,300	-69,300	-69,300
1	3,922	3,922	-65,378
2	4,145	4,145	-61,233
3	4,379	4,379	-56,854
4	4,626	4,626	-52,228
5	4,055	4,055	-48,173
6	5,159	5,159	-43,014
7	5,447	5,447	-37,566
8	5,750	5,750	-31,816
9	6,069	6,069	-25,747
10	5,022	5,022	-20,726
11	6,755	6,755	-13,970
12	7,125	7,125	-6,846
13	7,512	7,512	667
14	7,919	7,919	8,586
15	6,048	6,048	14,634
16	8,792	8,792	23,426
17	9,260	9,260	32,686
18	9,749	9,749	42,436
19	10,261	10,261	52,697
20	6,977	6,977	59,674

Table 14

The graph in Figure shows the cumulative cash flow over the project life.

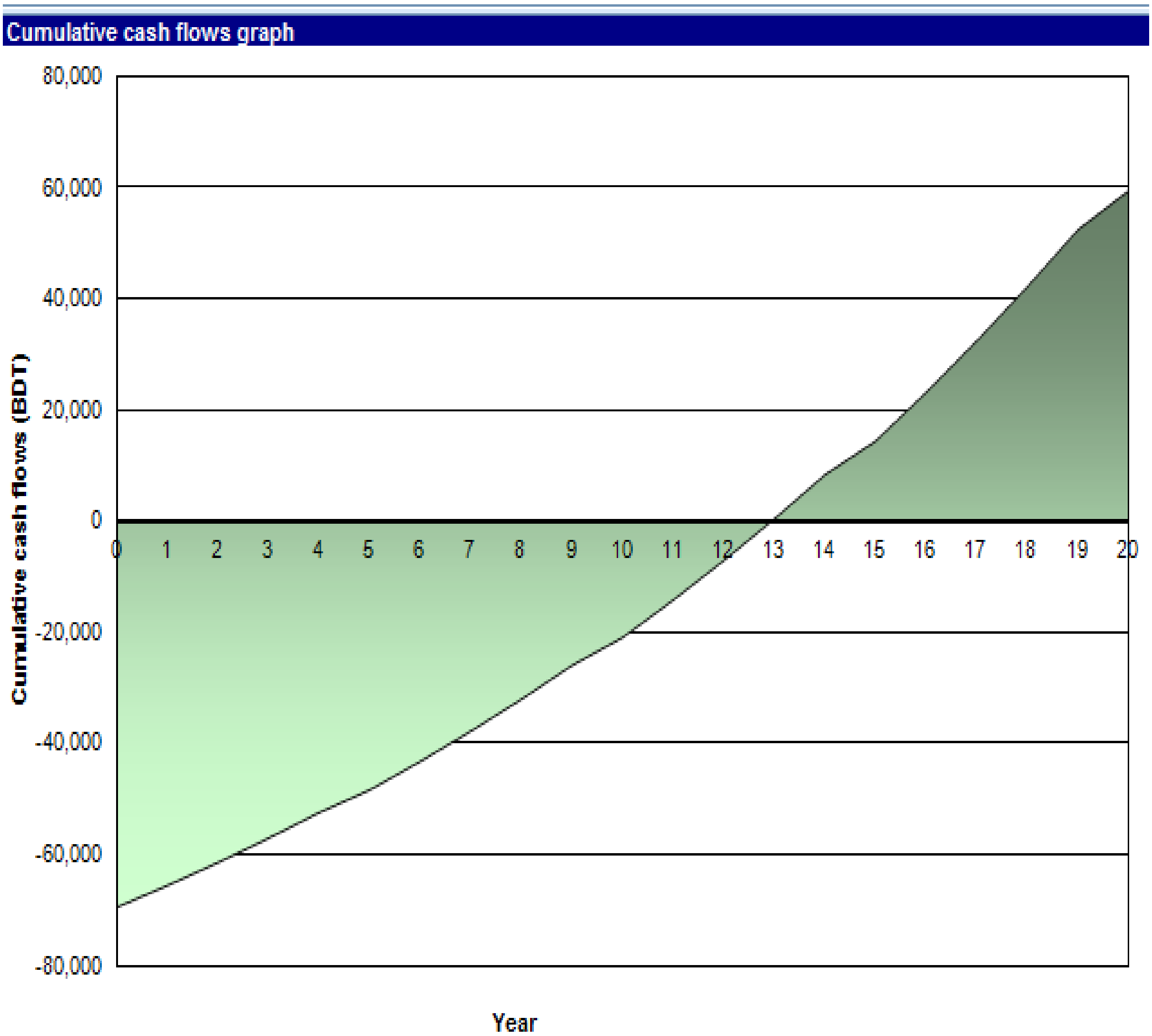


Figure 8

Sensitivity and Risk Analysis:

As part of the RETScreen Clean Energy Project Analysis Software, a Sensitivity and Risk Analysis worksheet is provided to help the user estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. This standard sensitivity and risk analysis worksheet contains a settings section and two main sections: Sensitivity analysis and Risk analysis. Each section provides information on the relationship between the key parameters and the important financial indicators, showing the parameters which have the greatest impact on the financial indicators. The Sensitivity analysis section is intended for general use, while the Risk analysis section, which performs a Monte Carlo simulation, is intended for users with knowledge of statistics.

This section presents the results of the sensitivity analysis. Each table shows what happens to the selected financial indicator (e.g. After-tax IRR – equity) when two key parameters (e.g. Initial costs and O&M) are varied by the indicated percentages. Parameters are varied using the following fraction of the sensitivity range: -1, -1/2, 0, 1/2, 1. Original values (which appear in the *Financial Analysis* worksheet) are in bold in these sensitivity analysis results tables. Results which indicate an unviable project, as defined by the user.Threshold, will appear as orange cells in these sensitivity analysis results table.

Sensitivity analysis

Perform analysis on	Net Present Value (NPV)
Sensitivity range	20%
Threshold	59674 BDT

Fuel cost - base case		O&M				BDT
		200	225	250	275	300
BDT		-20%	-10%	0%	10%	20%
3,169	-20%	32,213	30,496	28,780	27,063	25,346
3,565	-10%	47,660	45,943	44,227	42,510	40,793
3,962	0%	63,107	61,390	**59,674**	57,957	56,240
4,358	10%	78,554	76,837	75,121	73,404	71,687
4,754	20%	94,001	92,284	90,568	88,851	87,134

Fuel cost - proposed case		Initial costs				BDT
		55,440	62,370	69,300	76,230	83,160
BDT		-20%	-10%	0%	10%	20%
0	-20%	73,534	66,604	59,674	52,744	45,814
0	-10%	73,534	66,604	59,674	52,744	45,814
0	0%	73,534	66,604	**59,674**	52,744	45,814
0	10%	73,534	66,604	59,674	52,744	45,814
0	20%	73,534	66,604	59,674	52,744	45,814

Debt interest rate		Initial costs				BDT
		55,440	62,370	69,300	76,230	83,160
%		-20%	-10%	0%	10%	20%
0.00%	-20%	73,534	66,604	59,674	52,744	45,814
0.00%	-10%	73,534	66,604	59,674	52,744	45,814
0.00%	0%	73,534	66,604	**59,674**	52,744	45,814
0.00%	10%	73,534	66,604	59,674	52,744	45,814
0.00%	20%	73,534	66,604	59,674	52,744	45,814

Table 15

The above chart shows the range of sensibility for which our NPV will still be feasible to accept this project. The orange color cells represent the viability range of the change of parameters.

In the risk analysis section, the impact of each input parameter on a financial indicator is obtained by applying a standardized multiple linear regression on the financial indicator.

This section allows the user to perform a risk analysis by specifying the uncertainty associated with a number of key input parameters and to evaluate the impact of this uncertainty on after-tax IRR - equity, after-tax IRR - assets, equity payback or Net Present Value (NPV).

The risk analysis is performed using a Monte Carlo simulation that includes 500 possible combinations of input variables resulting in 500 values of after-tax IRR - equity, after-tax IRR - assets, equity payback or Net Present Value (NPV). The risk analysis allows the user to assess if the variability of the financial indicator is acceptable, or not, by looking at the distribution of the possible outcomes. An unacceptable variability will be an indication of a need to put more effort into reducing the uncertainty associated with the input parameters that were identified as having the greatest impact on the financial indicator.

Risk analysis

Perform analysis on: Net Present Value (NPV)

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	BDT	69,300	15%	58,905	79,695
O&M	BDT	250	10%	225	275
Fuel cost - base case	BDT	3,962	15%	3,367	4,556
Debt term	yr	0		0	0

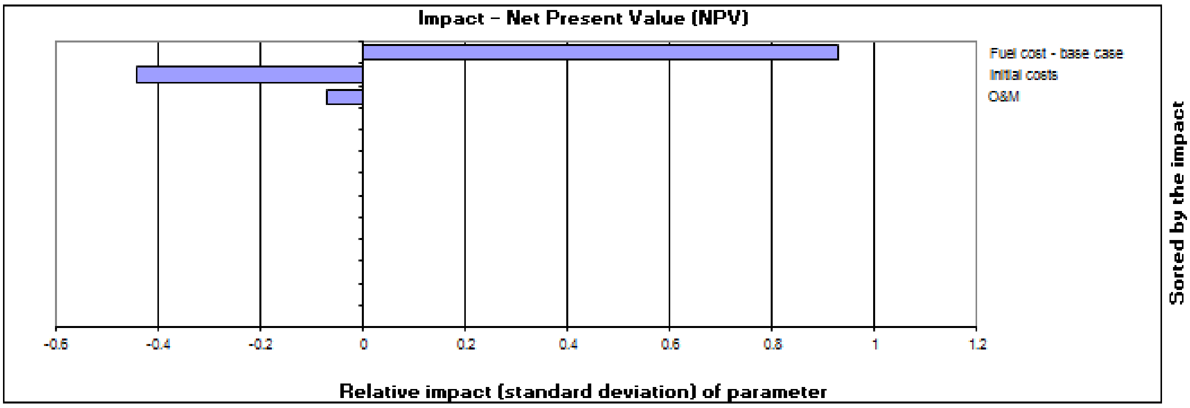


Table 16

Median	BDT	59,366
Level of risk	%	20.0%
Minimum within level of confidence	BDT	49,230
Maximum within level of confidence	BDT	70,243

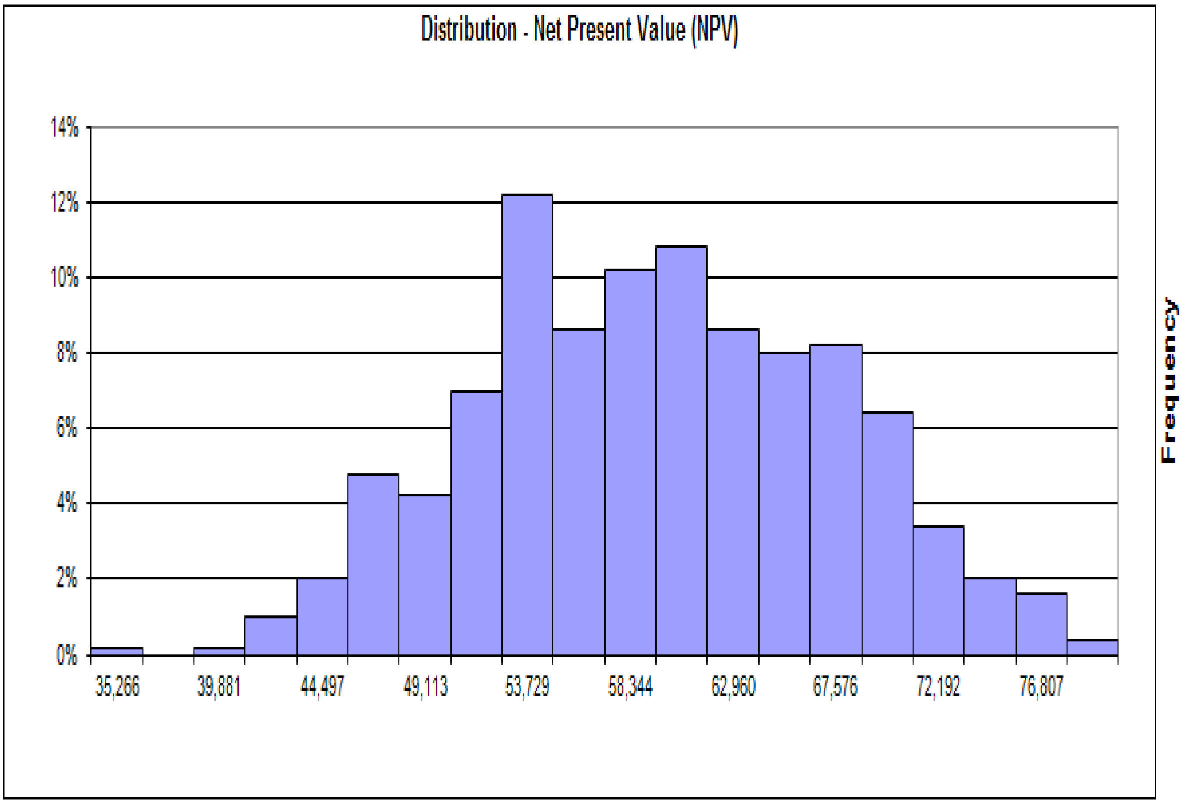


Table 17

The above chart represents the range of values of NPV (49730-70243Tk), for which our project has the viability.

Conclusion:

From our analysis it has been identified that solar irrigation system is feasible for small pumps for surface water irrigation .Well, no conclusion can be drawn if this solar system idea is also feasible for larger capacity of pump or submersible pump. It is also seen that after 13 years the project seems to become a way of income to the poor as it generates cash flows. The project would have been more profitable and feasible if the same system integral with a battery could be used to generate electricity during rainy season ,as there is plenty of natural water for irrigation.

Bibliography:

[1] =The economic value of water in the Ganges-Brahmaputra-Meghna river basin, Nasima Tanveer Chowdhury

[2] =SWERA project ,2007

Introduction:

Bangladesh is a agricultural country with its 36 % GDP based on agriculture.64% of employment is due to this reason. The national demand of electricity is 5000 MW but production available is3500 MW. Among the people only 35% has access to electricity and only 13.5% (760 MW) is used as irrigational electricity.

The irrigation system of Bangladesh comprises of three types of pumps ,namely-

4. Shallow Tube Well (STW)
5. Deep Tube Well (DTW)
6. Low Lift Pump (LLP)

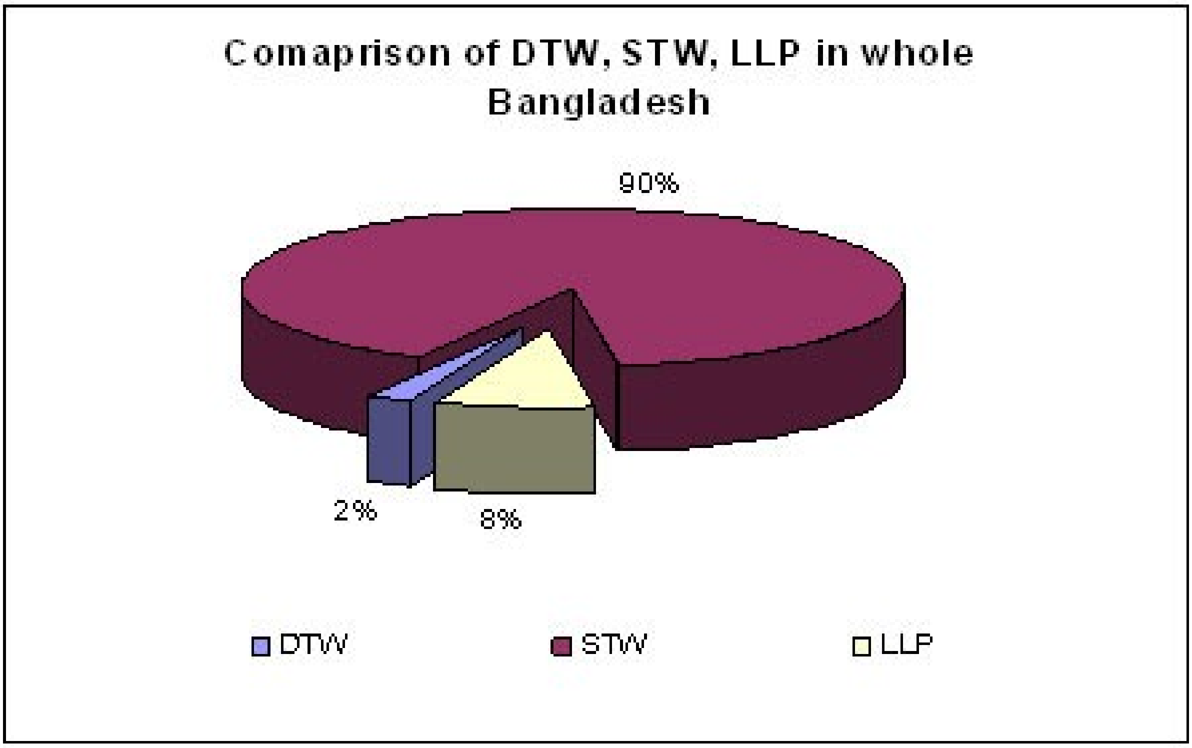
A brief description of Bangladesh Irrigation System is tabulated in chart

Organization Wise Summary of Irrigation Equipment Used, Area Irrigated and Benefited Farmers: 2010-11

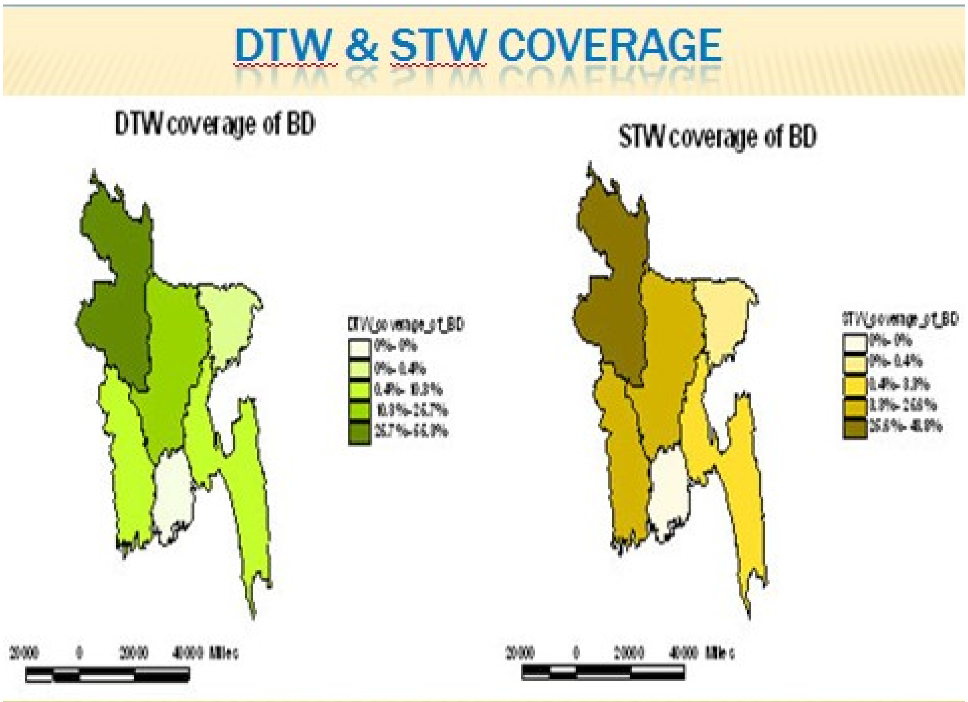
Type of Equipment	Name of organization	Operated by Electricity					Operated by Diesel			Total		
		Unit			Irrigated Area(hec.)	No of Farmers	Unit	Irrigated Area(hec.)	No of Farmers	Unit	Irrigated Area(hec.)	No of Farmers
		PDB	REB	TOTAL								
DTW	BADC	885	11298	12183	297708	821906	1647	36615	91560	13830	334323	913466
	BMDA	770	12041	12811	285189	706278	11	247	567	12822	285436	706845
	Others	476	5215	5691	83486	446978	1327	15961	73101	7018	99447	520079
	Total	2131	28554	30685	666383	1975162	2985	52823	165228	33670	719206	2140390
STW	BADC	8	42	50	155	530	88	260	890	138	415	1420
	BMDA	0	0	0	0	0	0	0	0	0	0	0
	Others	21291	206367	227658	531231	2348413	1321353	2973641	8164262	1549011	3504872	10512675
	Total	21299	206409	227708	531386	2348943	1321441	2973901	8165152	1549149	3505287	10514095
LLP	BADC	117	664	781	31613	76274	3232	35729	97067	4013	67342	173341
	BMDA	10	15	25	836	1394	0	0	0	25	836	1394
	Others	1277	8232	9509	59431	415694	160122	882372	1985425	169631	941803	2401119
	Total	1404	8911	10315	91880	493362	163354	918101	2082492	173669	1009981	2575854
DTW +STW +LLP		24834	243874	268708	1083573	4817467	1487780	4046689	10412872	1756488	5234474	15230339
Manual & Artesian Well		0	0	0	0	0	0	0	0	0	6381	3191
Traditional Method		0	0	0	0	0	0	0	0	0	3814	4504
Gravity Flow		0	0	0	0	0	0	0	0	0	19071	25235
COUNTRY TOTAL		24834	243874	268708	1083573	4817467	1487780	4046689	10412872	1756488	5263740	15263269

Table 1

From the above chart it is easily describable that 90 % of the pumps are STW type and this ratio can be shown as-



The pie chart above distinguishes the methods of irrigation in Bangladesh. The STW leads the table. The coverage of STW and DTW are shown in the next figure1, which resembles a Bangladesh map.



It is also found that about 85% of these STW are diesel run and this causes the government to use a large portion of its irrigation budget to be spent on subsidy only.

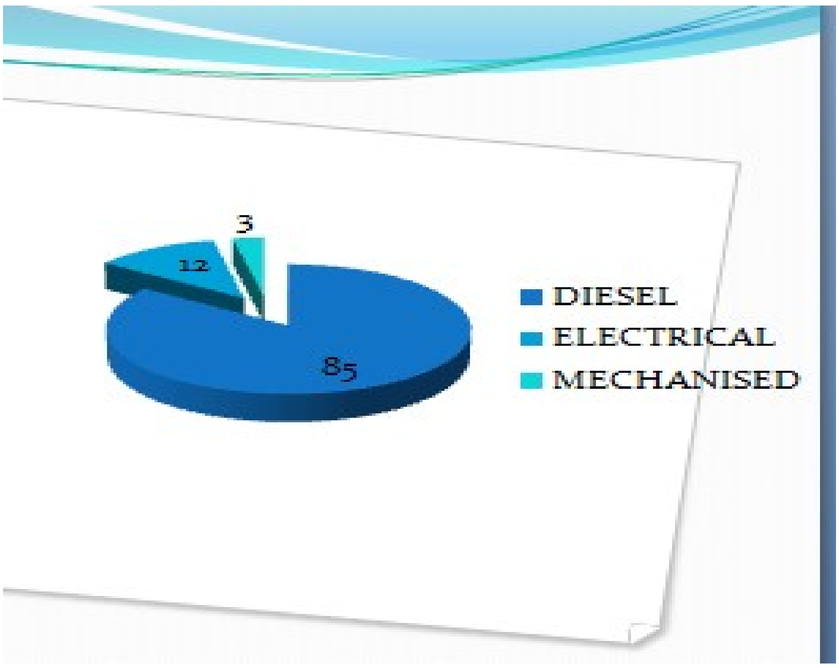


FIG: PUMP OPERATION

So, our main focus is to replace these STW (90% of pump), with solar irrigation pump and thus to reduce the subsidy and thus ultimately reducing the irrigation cost of farmer.

Prospect of solar irrigation in Bangladesh:

Bangladesh is located in the Tropical region bestowed with direct solar insulation .This fact comprises the possibility that solar irrigation system should be practical and feasible in Bangladesh. The NASA provides us with the data below in chart

MONTH	Solar radiation (Wh/m2	
	NASA	RECORDED
JAN	4.32	3.96
FEB	5.25	4.47
MARCH	5.95	5.88
APRIL	6.33	6.24
MAY	5.74	6.17
JUNE	5.04	5.25
JULY	4.41	4.79
AUG	4.36	5.16
SEP	4.03	4.96
OCT	4.42	4.88
NOV	4.46	4.42
DEC	4.21	3.82

Table 2

This can also be shown as below in figure 2

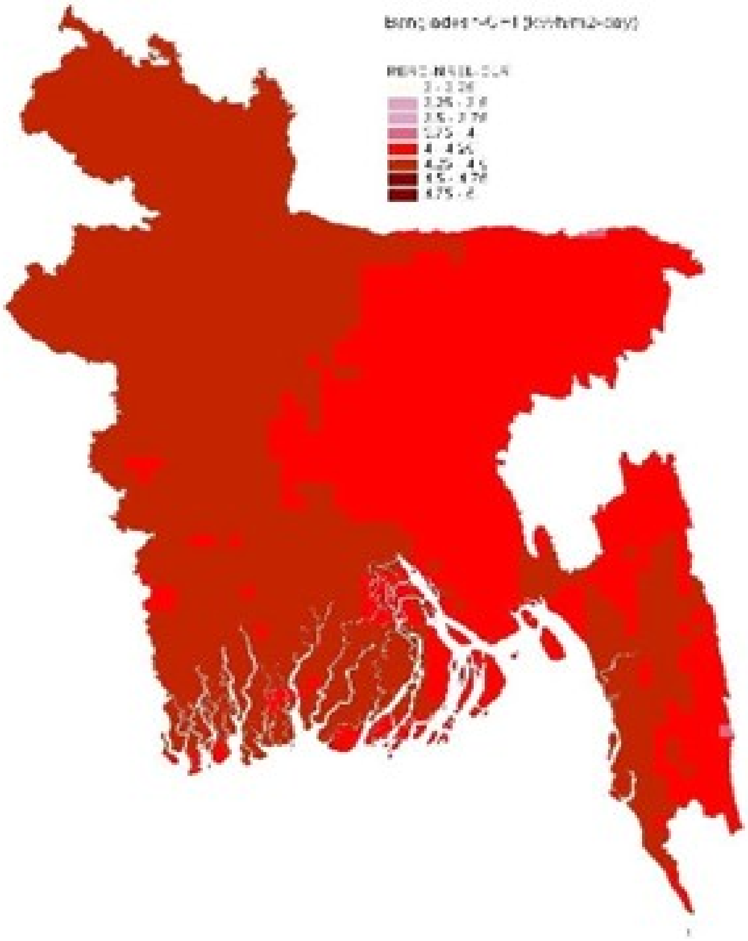


Fig 2: Global Horizontal Irradiance map of Renewable Energy Research Centre (RERC)-National Renewable Energy Laboratory (NREL) - *German* Aerospace Center (*DLR*) showing averaged NREL and DLR maps tuned to Dhaka

FIG : 2

As it’s not feasible to carry our experiment throughout Bangladesh, we will select an area and thus collect sufficient data for that region and carry out our experiment. In this case we have taken BARI, Gajipur as our target area.

The Practical Data:

The data were collected from BARI. A typical August morning was chosen and the data were collected.

We used a pump, solar panels, flow meter to record data for surface irrigation. The specification is listed below-

Pump:

Brand –honewell

RPM-1900

Capacity-0.5hp

Solar Panel:

Brand-Tata

Nos-4

Capacity-75 w/panel

Head:

Suction head: 1.1 m

Discharge head: 0.8m

Drawdown head: 0.2 m

The figure :3,4,5,6 shows the experimental set up in the next page

Figure 3

Figure 4

Figure 5

Figure 6

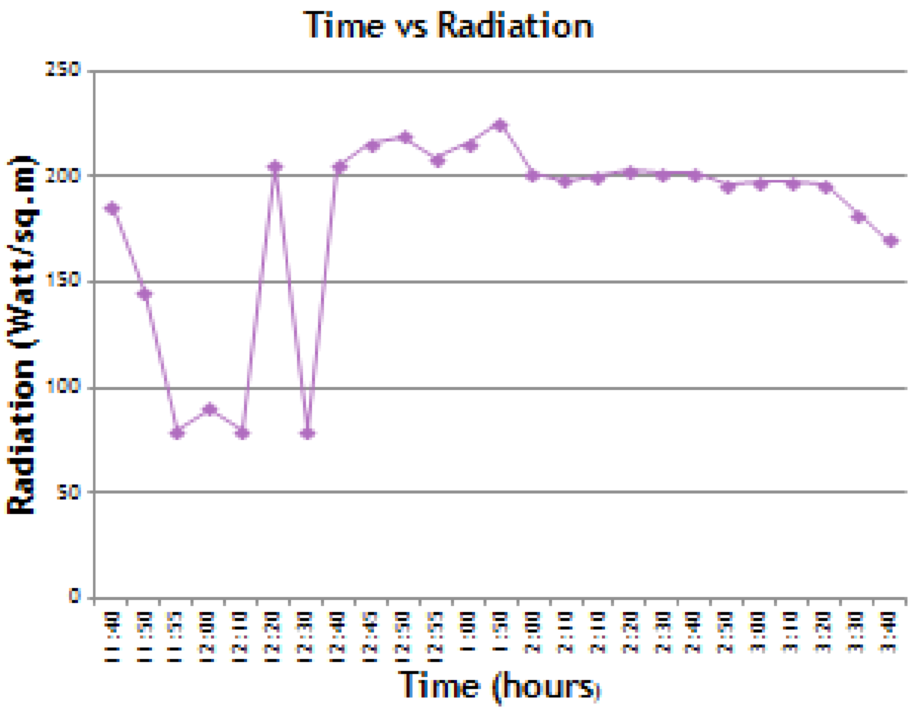
The recorded data are tabulated in chart

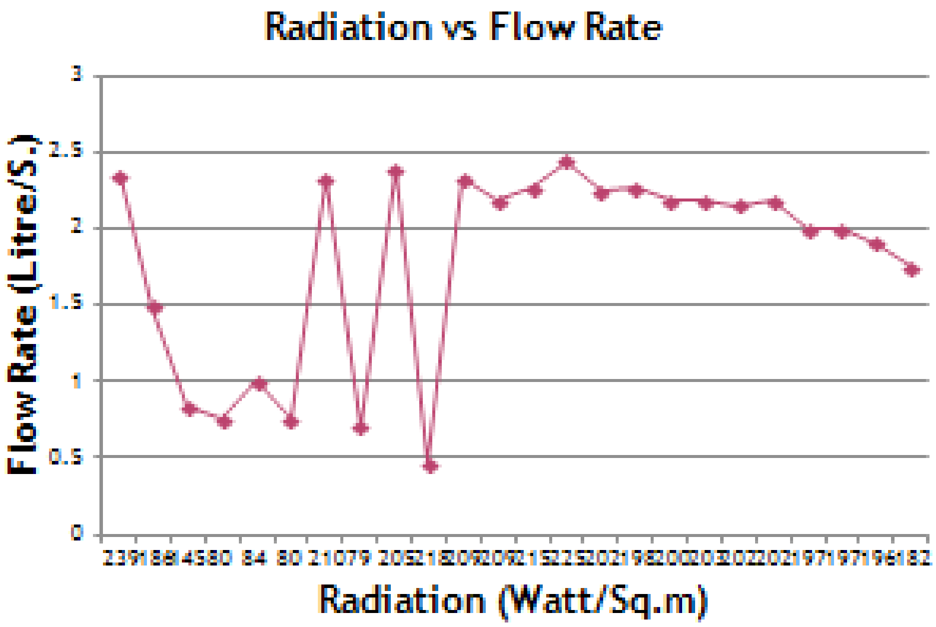
Time(hrs)	Radiation (W/sq m)	Time taken to discharge 100 litre of water(sec)	Flow rate (L/s)	Discharge (m3) Initially-73.06 m3
11:30	239	42.7	2.34	
11:40	186	67	1.49	
11:50	145	120	0.83	
11:55	80	134	0.75	
12:00	84	100	1	
12:10	80	132	0.757	
12:20	210	43	2.325	
12:30	79	142	0.7	
12:40	205	42	2.39	
12:45	218	41	0.46	
12:50	209	43	2.325	
Cont...				
12:55	209	46	2.174	
1:00	215	44	2.27	
1:50	225	41	2.44	
2:00	202	44.5	2.24	
2:10	198	44.3	2.257	
2:20	200	46	2.174	
2:30	203	46.	2.174	
2:40	202	46.5	2.15	
2:50	202	46	2.174	
3:00	197	50	2	
3:10	197	50	2	

Cont...				
12:55	209	46	2.174	
1:00	215	44	2.27	
1:50	225	41	2.44	
2:00	202	44.5	2.24	
2:10	198	44.3	2.257	
2:20	200	46	2.174	
2:30	203	46.	2.174	
2:40	202	46.5	2.15	
2:50	202	46	2.174	
3:00	197	50	2	
3:10	197	50	2	
3:20	196	52	1.9	
3:30	182	57.5	1.74	95.1

Table 3

The graphical representation is shown in figure


Time vs Radiation
Radiation (Watt/sq.m)
250
200
150
100
50
0
Time (hours)


Radiation vs Flow Rate
Flow Rate (Litre/S.)
3
2.5
2
1.5
1
0.5
0
Radiation (Watt/Sq.m)

Experiment results:

From graphs, we can see that the solar radiation fluctuates till 1:00 pm but after that it maintains a steady value. This may be due to the cloudy forecast that we had on that day.

In respond to the radiation fluctuation, the flow rate also fluctuates till 1:00 pm, and after that it maintains a steady balance value

Practically there was no water pumping below 18 watt/sqm. So the critical radiation is 18 watt/sqm .

Our next step is to put this practical data to RETScreen software to analyze the result for the project to be viable.

Software Analysis

The entire project has been simulated through RETScreen Renewable Energy Software. This software is used to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs).It follows five steps to evaluate any project. The steps are

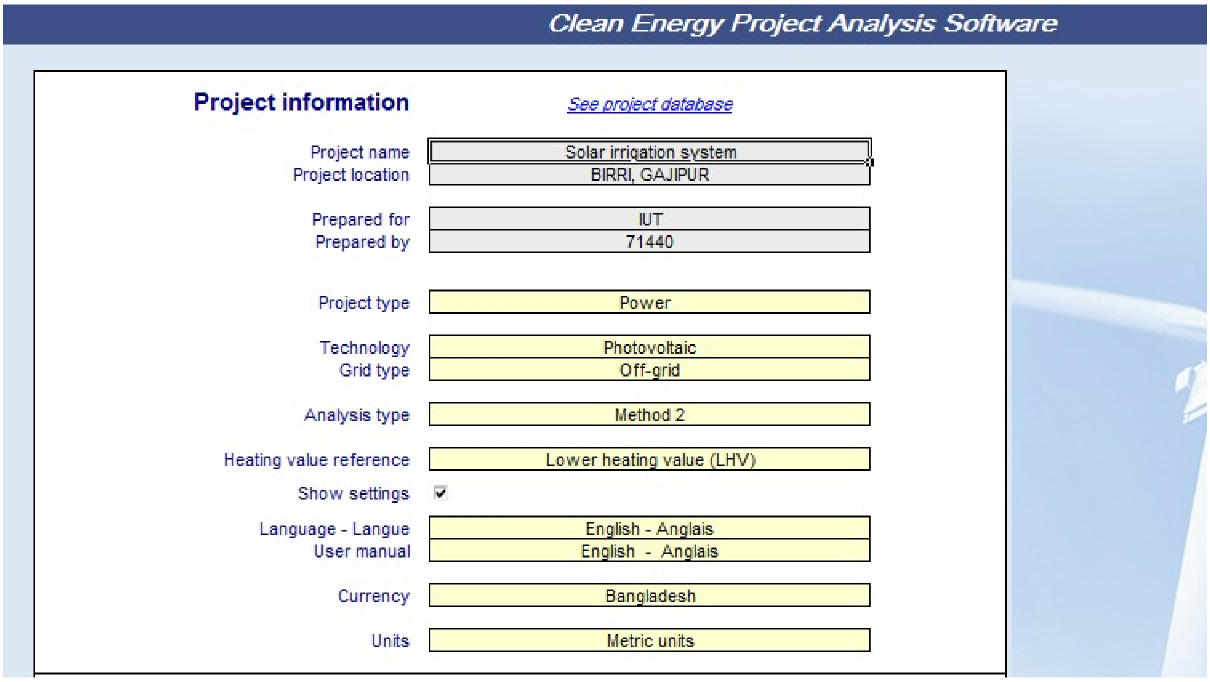
7. Start
8. Energy model
9. Cost Analysis
10. Emission Analysis
11. Financial Analysis

12. Sensibility and Risk Analysis

To evaluate my project ,I followed the above mentioned steps using the data obtained during our observation of the project at BARI.

Start:

This part of the software describes the project name, location, method of analysis. I have used the method 2 procedure as this gives more accurate result.



Clean Energy Project Analysis Software

Project information See project database

Project name	Solar irrigation system
Project location	BIRRI, GAJIPUR
Prepared for	IUT
Prepared by	71440
Project type	Power
Technology	Photovoltaic
Grid type	Off-grid
Analysis type	Method 2
Heating value reference	Lower heating value (LHV)
Show settings	☑
Language - Langue	English - Anglais
User manual	English - Anglais
Currency	Bangladesh
Units	Metric units

Table 4

All currency is mentioned in Taka for better understanding of the project viability. I preferred off grid technology as our system was not connected to any external grid..

Water Pumping:

My priority is to satisfy the irrigation need during the month of BORRO, as it is mostly grown in Bangladesh and needs to be planted during Nov-Dec. And there is scarcity of ground water during this time of the year. The pump parameters are calculated from the data. From chart we find that our pump

delivers 22.04 m3of water

We require 11500 m3hectare of water for BORO[1].So ,if we assume to run

our pump 8 hours a day and for two and half months (75 days) then we need to

pump 146 m3of water daily.Our experiment pump drives only 22.04 m3of

water in 3hours and 20 minutes.So we can pump 53m3of water in 8 hours

,which is sufficient for only 0.363 hectares of land .This data has been provided to the RETScreen and it thus gives us output as to how much daily and annual electricity will be needed for irrigating 0.363 hectares of land. The output provided is 1.56 kwh of electricity .This output is then used in the Energy model of the software.

Water pumping

Load characteristics

○ Method 1
◉ Method 2

						Base case		Proposed case	
Description	**Application**	**Unit**	**Quantity**	**Daily water use per unit**		**Daily water use** m^3/d		**Water use reduction** %	**Daily water use** m^3/d
Rice field	Irrigation	ha	0.363	$m^3/d/ha$	146	53.00		0%	53.00

		Base case	Proposed case
Daily water use	m^3/d	53.00	53.00
Suction head	m	1.1	1.1
Drawdown	m	0.2	0.2
Discharge head	m	0.8	0.8
Pressure head	m	0.0	0.0
Friction losses	%	3%	3%
Total head	m	2.1	2.2
Mechanical energy - daily	kWh	0.30	0.31
Mechanical energy - annual	kWh	109.1	114.0
Pump & motor			
Description		centrifugal	centrifugal
Type		DC	DC
Efficiency	%	20%	20%
Summary			
Electricity - daily	kWh	1.49	1.56
Electricity - annual	kWh	545.66	570.09

Table 5

Energy model:

In this portion ,I highlighted on the load that our system has to provide.The only load is a 0.3 KW centrifugal pump. Both loads for the proposed case(solar irrigation) and the Base case(diesel engine irrigation) are assumed to be same .

I used Tk 61 as the current diesel price in Bangladesh which gives me Base case load DC load to be 60.8 watt .It is shown in Figure7 also used as the heating

value as 13000kjkwh from the Figure.

RETScreen Energy Model - Power project

Power project

Base case power system

Grid type		Off-grid
Technology		Reciprocating engine
Fuel type		Diesel (#2 oil) - L
Fuel rate	BDT/L	61.000
Capacity	kW	
Heat rate	kJ/kWh	13,000
Annual O&M cost	BDT	0
Electricity rate - base case	BDT/kWh	21.854
Total electricity cost	BDT	3,962

Load characteristics

○ Method 1
⊙ Method 2

Description	AC/DC	Intermittent resource-load correlation	Base case load W	Hours of use per day h/d	Days of use per week d/w	Proposed case load reduction %	Proposed case usage time reduction %
pump	DC	Positive	62.08	8.00	7	0%	0%

Table 6

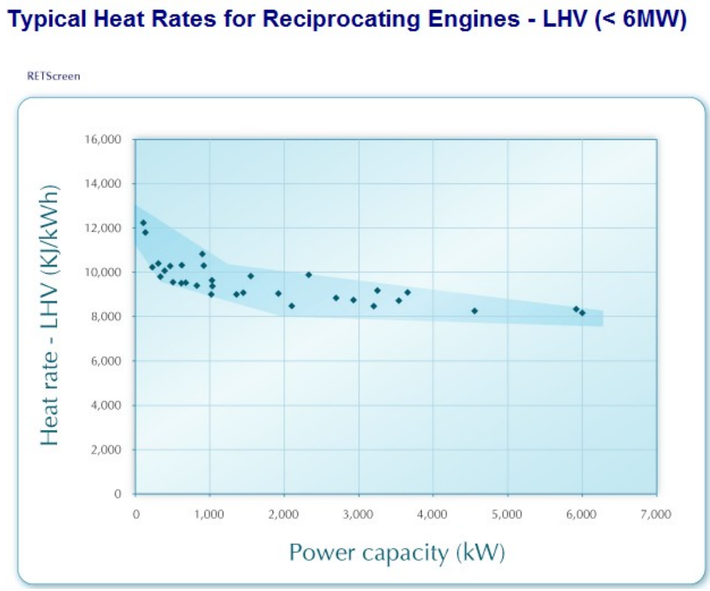


Figure 7

For the proposed case I took the daily radiation data from the NASA meteorological center for Gazipur(24.8 N,90.4 E).It is shown

Proposed case power system

Inverter

Capacity	kW	0.0	Peak load - annual - AC

Battery

Days of autonomy	d	0.0

Technology Photovoltaic

Resource assessment

Solar tracking mode		Fixed
Slope	°	25.0
Azimuth	°	0.0

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity delivered to load MWh
January	4.37	5.74	0.02
February	5.08	6.11	0.01
March	5.81	6.31	0.02
April	5.86	5.78	0.01
May	5.19	4.84	0.02
June	4.47	4.10	0.01
July	4.12	3.83	0.02
August	4.11	3.96	0.02
September	3.82	3.89	0.01
October	4.31	4.87	0.02
November	4.38	5.58	0.01
December	4.19	5.67	0.02
Annual	**4.64**	**5.05**	**0.18**

Annual solar radiation - horizontal	MWh/m²	1.69
Annual solar radiation - tilted	MWh/m²	1.84

Table 7

The experiment set up has 4 -75 watt si-monocrystalline solar panel with an efficiency of approx 16% [2].No battery is used as no energy is stored and no inverter is used as we are using a DC pump. The RETScreen shows the below data

Photovoltaic

Type		mono-Si	
Power capacity	kW	0.30	
Manufacturer		TATA	
Model			
Efficiency	%	16.0%	
Nominal operating cell temperature	°C	45	
Temperature coefficient	% / °C	0.40%	
Solar collector area	m²	1.9	
Control method		Maximum power point tracker	
Miscellaneous losses	%	0.0%	

Summary

Capacity factor	%	19.4%	
Electricity delivered to load	MWh	0.18	100.0%

Cost Analysis:

In this portion RETScreen deals with the costing of the project by identifying the initial cost, maintenance cost, fuel cost etc. Our project encounters costs like solar panel cost(100tk for 1watt),pump and motor cost(25000tk),boring cost(50tk for 20ft),transportation cost (1000tk),engineering cost(5000tk),collector support structure(2000tk) and contingencies of 10%. The contingency allowance should be included to account for unforeseen annual expenses and will depend on the level of accuracy of the operation and maintenance cost estimate section. It typically ranges from 10 to 20% of these costs. We have taken 10%of contingency. The cost analysis is shown in figure

Initial costs (credits)	Unit	Quantity	Unit cost		Amount		Relative costs
Feasibility study							
Feasibility study	cost	0	BDT	-	BDT	-	
Subtotal:					**BDT**	**-**	0.0%
Development							
Development	cost	0	BDT	-	BDT	-	
Subtotal:					**BDT**	**-**	0.0%
Engineering							
Engineering	cost	1	BDT	5,000	BDT	5,000	
Subtotal:					**BDT**	**5,000**	7.2%
Power system							
Photovoltaic	kW	0.30	BDT	100,000	BDT	30,000	
Road construction	km	0			BDT	-	
Transmission line	km	0			BDT	-	
Substation	project	0			BDT	-	
Energy efficiency measures	project	0			BDT	-	
Collector support structure	cost	1	BDT	2,000	BDT	2,000	
					BDT	-	
Subtotal:					**BDT**	**32,000**	46.2%
Balance of system & miscellaneous							
Spare parts	%	0.0%			BDT	-	
Transportation	project	1	BDT	1,000	BDT	1,000	
Training & commissioning	p-d				BDT	-	
pump,motor,pipe line	cost	1	BDT	25,000	BDT	25,000	
Contingencies	%	10.0%	BDT	63,000	BDT	6,300	
Interest during construction	0.00%	0 month(s)	BDT	69,300	BDT	-	
Subtotal:					**BDT**	**32,300**	46.6%
Total initial costs					**BDT**	**69,300**	100.0%

Annual costs (credits)	Unit	Quantity	Unit cost		Amount	
O&M						
Parts & labour	project	1	BDT	200	BDT	200
boring	cost	1	BDT	50	BDT	50
Contingencies	%		BDT	250	BDT	-
Subtotal:					**BDT**	**250**

Annual savings	Unit	Quantity	Unit cost		Amount	
Fuel cost - base case						
Diesel (#2 oil)	L	65	BDT	61.000	BDT	3,962
Subtotal:					**BDT**	**3,962**

Periodic costs (credits)	Unit	Year	Unit cost		Amount	
pump (overhaul)	cost	5	BDT	500	BDT	500
					BDT	-
End of project life	credit				BDT	-

Table 8

As part of the RETScreen Clean Energy Project Analysis Software, an Emission Analysis worksheet is provided to estimate the greenhouse gas emission reduction (mitigation) potential of the proposed project. It also provides GHG global warming potential factors. The Base case electricity system and Base case system GHG summary sections provide a description of the emission profile of the baseline system. The Proposed case system GHG summary section provides a description of the emission profile of the proposed project. The GHG emission reduction summary section provides a summary of the estimated GHG emission reduction based on the data entered by the user in the preceding sections. Results are calculated as equivalent tones of CO2 avoided per annum.

The emission reduction of our project is shown in figure

RETScreen Emission Reduction Analysis - Power project

Emission Analysis

- Method 1
- Method 2 (selected)
- Method 3

Global warming potential of GHG

25 tonnes CO2 =	1 tonne CH4	(IPCC 2007)
298 tonnes CO2 =	1 tonne N2O	(IPCC 2007)

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	emission factor kg/GJ	CH4 emission factor kg/GJ	N2O emission factor kg/GJ	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Diesel (#2 oil)	100.0%	73.3	0.0020	0.0020	1	0.266	0.2
Total	100.0%	73.3	0.0020	0.0020	1	0.266	0.2

Proposed case system GHG summary (Power project)

Fuel type	Fuel mix %	emission factor kg/GJ	CH4 emission factor kg/GJ	N2O emission factor kg/GJ	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Solar	100.0%	0.0	0.0000	0.0000	0	0.000	0.0
Total	100.0%	0.0	0.0000	0.0000	0	0.000	0.0

Table 9

As we see, our project reduces carbon di oxide use by 0.2 ton. It also resembles this statistics as other parameter. Reducing carbon- di- oxide use by 0.2 tones resembles 85.9 liters of gasoline not being consumed.

GHG emission reduction summary							
	Base case GHG emission tCO2	Proposed case GHG emission tCO2			Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Power project	0.2	0.0			0.2		0.2
Net annual GHG emission reduction	0.2	tCO2	is equivalent to	85.9	Litres of gasoline not consumed		

Table 10

Financial Analysis:

One of the primary benefits of using the RETScreen software is that it facilitates the project evaluation process for decision-makers. The *Financial Analysis* worksheet, with its financial parameters input items (e.g. discount rate, debt ratio, etc.), and its calculated financial viability output items (e.g. IRR, simple payback, NPV, etc.), allows the project decision-maker to consider various financial parameters with relative ease.

In our project, we have taken the inflation rate as 10.7 (World Bank 2012),fuel escalation rate as 6%.We have also taken the project life to be 20 years. The total project being financed by the owner itself so no grant or subsidy is taken into account. The annual income which considered is only that of GHG reduction ..

RETScreen Financial Analysis - Power project

Financial parameters		
General		
Fuel cost escalation rate	%	6.0%
Inflation rate	%	10.7%
Discount rate	%	0.0%
Project life	yr	20
Finance		
Incentives and grants	BDT	0
Debt ratio	%	

Table 11

Many of the summary items here are calculated and/or entered in the *Cost Analysis* worksheet and transferred to the *Financial Analysis* worksheet. The remainder are calculated and/or entered in other parts of the *Financial Analysis* worksheet.

The total initial costs represent the total incremental investment that must be made to bring the proposed case project on line, before it begins to generate savings and/or income. The total initial costs are the sum of the estimated feasibility study, development, engineering, power system.

The total annual costs are calculated by the model and represent the yearly costs incurred to operate, maintain and finance the project. It is the sum of the O&M, fuel cost for the proposed case system and debt payments

The periodic costs and periodic credits are entered by the user in the *Cost Analysis* worksheet and are transferred here. The model escalates the periodic costs and credits yearly according to the inflation rate starting from year 1 and throughout the project life.

Project costs and savings/income summary			
Initial costs			
Engineering	7.2%	BDT	5,000
Power system	46.2%	BDT	32,000
Balance of system & misc.	46.6%	BDT	32,300
Total initial costs	**100.0%**	**BDT**	**69,300**
Annual costs and debt payments			
O&M		BDT	250
Fuel cost - proposed case		BDT	0
Total annual costs		**BDT**	**250**
Periodic costs (credits)			
pump (overhaul) - 5 yrs		BDT	500
Annual savings and income			
Fuel cost - base case		BDT	3,962
Total annual savings and income		**BDT**	**3,962**

Table 12

The results from the financial viability portion provide the decision-maker with various financial indicators for the proposed case project.

The model calculates the pre-tax internal rate of return (IRR) on equity (%), which represents the true interest yield provided by the project equity over its life before income tax. If the internal rate of return is equal to or greater than the required rate of return of the organization, then the project will likely be considered financially acceptable (assuming equal risk). If it is less than the required rate of return, the project is typically rejected

Financial viability		
Pre-tax IRR - equity	%	5.7%
Pre-tax IRR - assets	%	5.7%
After-tax IRR - equity	%	5.7%
After-tax IRR - assets	%	5.7%
Simple payback	yr	18.7
Equity payback	yr	12.9
Net Present Value (NPV)	BDT	59,674
Annual life cycle savings	BDT/yr	2,984
Benefit-Cost (B-C) ratio		1.86
GHG reduction cost	BDT/tCO2	(17,113)

Table 13

The model calculates the simple payback (year), which represents the length of time that it takes for a proposed project to recoup its own initial cost, out of the income or savings it generates. The simple payback method is not a measure of how profitable one project is compared to another. Rather, it is a measure of time in the sense that it indicates how many years are required to recover the investment for one project compared to another

The model calculates the Net Present Value (NPV) of the project, which is the value of all future cash flows, discounted at the discount rate, in today's currency. The difference between the present values of these cash flows, called the NPV, determines whether or not the project is generally a financially acceptable investment. Positive NPV values are an indicator of a potentially feasible project

The model calculates the net Benefit-Cost (B-C) ratio, which is the ratio of the net benefits to costs of the project. Net benefits represent the present value of annual income and savings less annual costs, while the cost is defined as the project equity. Ratios greater than 1 are indicative of profitable projects.
The model calculates the GHG reduction cost. The GHG reduction cost is calculated by dividing the annual life cycle savings of the project by the net GHG reduction per year, averaged over the project life.
The total annual savings and income represents the annual savings and/or income realized due to the implementation of the proposed case system.

The model calculates the annual GHG reduction income, which represents the income generated by the sale or exchange of the GHG reduction. This value is calculated from the annual net GHG reduction and the GHG reduction credit rate. The yearly value of GHG reduction income is escalated at the GHG reduction credit escalation rate.

Annual income		
Electricity export income		
GHG reduction income	☐	
Net GHG reduction	tCO_2/yr	0
Net GHG reduction - 20 yrs	tCO_2	3

The software also provides us with the yearly cash flow .Thus showing us the positive cash flow and the year it takes to attain that. For our project, the positive cash flow occurs at the 13th year and after 20 years of the project the project will generate about 59674 Tk.

Yearly cash flows			
Year	Pre-tax	After-tax	Cumulative
#	BDT	BDT	BDT
0	-69,300	-69,300	-69,300
1	3,922	3,922	-65,378
2	4,145	4,145	-61,233
3	4,379	4,379	-56,854
4	4,626	4,626	-52,228
5	4,055	4,055	-48,173
6	5,159	5,159	-43,014
7	5,447	5,447	-37,566
8	5,750	5,750	-31,816
9	6,069	6,069	-25,747
10	5,022	5,022	-20,726
11	6,755	6,755	-13,970
12	7,125	7,125	-6,846
13	7,512	7,512	667
14	7,919	7,919	8,586
15	6,048	6,048	14,634
16	8,792	8,792	23,426
17	9,260	9,260	32,686
18	9,749	9,749	42,436
19	10,261	10,261	52,697
20	6,977	6,977	59,674

Table 14

The graph in Figure shows the cumulative cash flow over the project life.

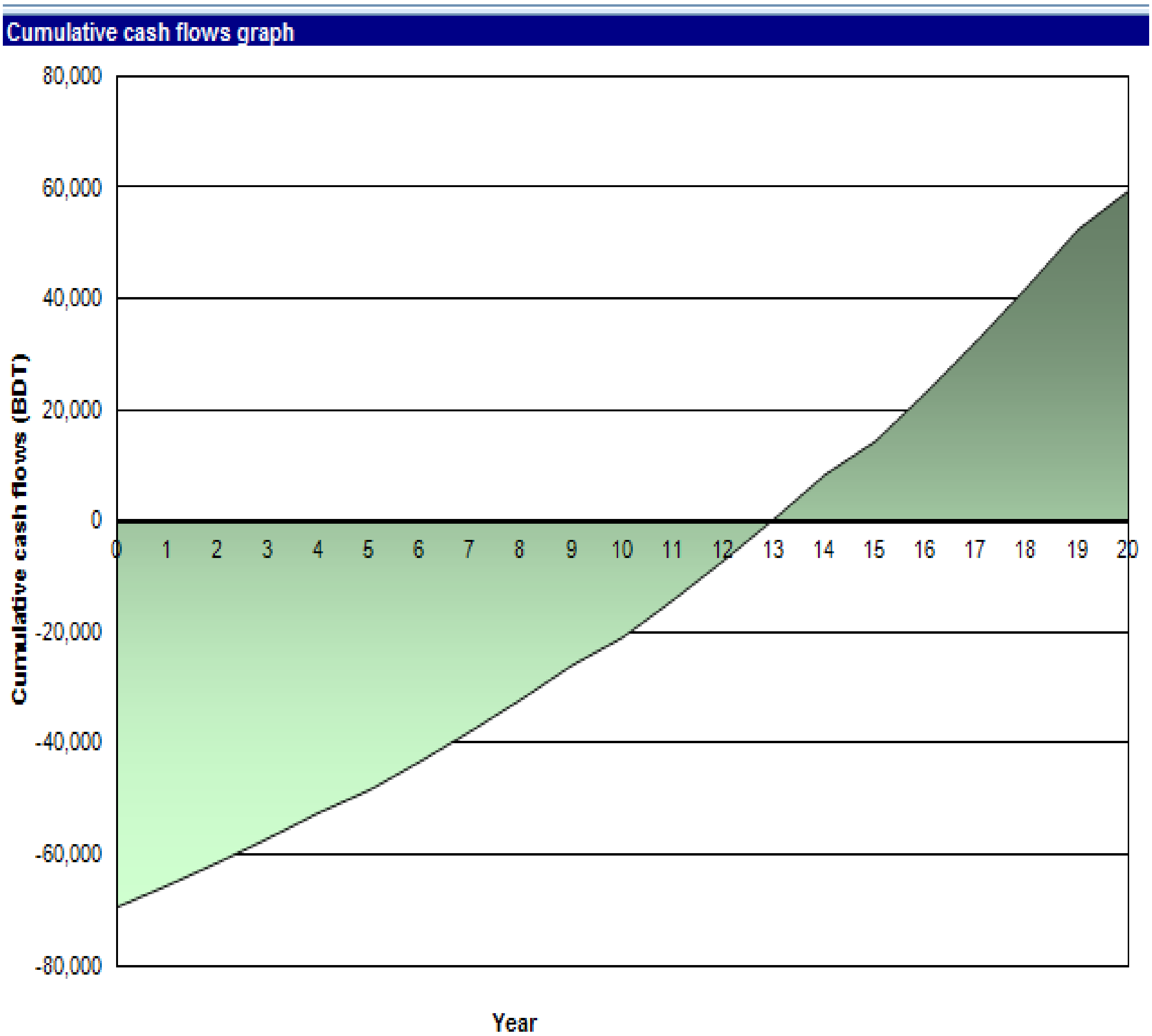


Figure 8

Sensitivity and Risk Analysis:

As part of the RETScreen Clean Energy Project Analysis Software, a Sensitivity and Risk Analysis worksheet is provided to help the user estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. This standard sensitivity and risk analysis worksheet contains a settings section and two main sections: Sensitivity analysis and Risk analysis. Each section provides information on the relationship between the key parameters and the important financial indicators, showing the parameters which have the greatest impact on the financial indicators. The Sensitivity analysis section is intended for general use, while the Risk analysis section, which performs a Monte Carlo simulation, is intended for users with knowledge of statistics.

This section presents the results of the sensitivity analysis. Each table shows what happens to the selected financial indicator (e.g. After-tax IRR – equity) when two key parameters (e.g. Initial costs and O&M) are varied by the indicated percentages. Parameters are varied using the following fraction of the sensitivity range: -1, -1/2, 0, 1/2, 1. Original values (which appear in the *Financial Analysis* worksheet) are in bold in these sensitivity analysis results tables. Results which indicate an unviable project, as defined by the user.Threshold, will appear as orange cells in these sensitivity analysis results table.

Sensitivity analysis

Perform analysis on	Net Present Value (NPV)	
Sensitivity range	20%	
Threshold	59674	BDT

Fuel cost - base case				O&M		BDT
		200	225	250	275	300
BDT		-20%	-10%	0%	10%	20%
3,169	-20%	32,213	30,496	28,780	27,063	25,346
3,565	-10%	47,660	45,943	44,227	42,510	40,793
3,962	0%	63,107	61,390	**59,674**	57,957	56,240
4,358	10%	78,554	76,837	75,121	73,404	71,687
4,754	20%	94,001	92,284	90,568	88,851	87,134

Fuel cost - proposed case				Initial costs		BDT
		55,440	62,370	69,300	76,230	83,160
BDT		-20%	-10%	0%	10%	20%
0	-20%	73,534	66,604	59,674	52,744	45,814
0	-10%	73,534	66,604	59,674	52,744	45,814
0	0%	73,534	66,604	**59,674**	52,744	45,814
0	10%	73,534	66,604	59,674	52,744	45,814
0	20%	73,534	66,604	59,674	52,744	45,814

Debt interest rate				Initial costs		BDT
		55,440	62,370	69,300	76,230	83,160
%		-20%	-10%	0%	10%	20%
0.00%	-20%	73,534	66,604	59,674	52,744	45,814
0.00%	-10%	73,534	66,604	59,674	52,744	45,814
0.00%	0%	73,534	66,604	**59,674**	52,744	45,814
0.00%	10%	73,534	66,604	59,674	52,744	45,814
0.00%	20%	73,534	66,604	59,674	52,744	45,814

Table 15

The above chart shows the range of sensibility for which our NPV will still be feasible to accept this project. The orange color cells represent the viability range of the change of parameters.

In the risk analysis section, the impact of each input parameter on a financial indicator is obtained by applying a standardized multiple linear regression on the financial indicator.

This section allows the user to perform a risk analysis by specifying the uncertainty associated with a number of key input parameters and to evaluate the impact of this uncertainty on after-tax IRR - equity, after-tax IRR - assets, equity payback or Net Present Value (NPV).

The risk analysis is performed using a Monte Carlo simulation that includes 500 possible combinations of input variables resulting in 500 values of after-tax IRR - equity, after-tax IRR - assets, equity payback or Net Present Value (NPV). The risk analysis allows the user to assess if the variability of the financial indicator is acceptable, or not, by looking at the distribution of the possible outcomes. An unacceptable variability will be an indication of a need to put more effort into reducing the uncertainty associated with the input parameters that were identified as having the greatest impact on the financial indicator.

Risk analysis

Perform analysis on: Net Present Value (NPV)

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	BDT	69,300	15%	58,905	79,695
O&M	BDT	250	10%	225	275
Fuel cost - base case	BDT	3,962	15%	3,367	4,556
Debt term	yr	0		0	0

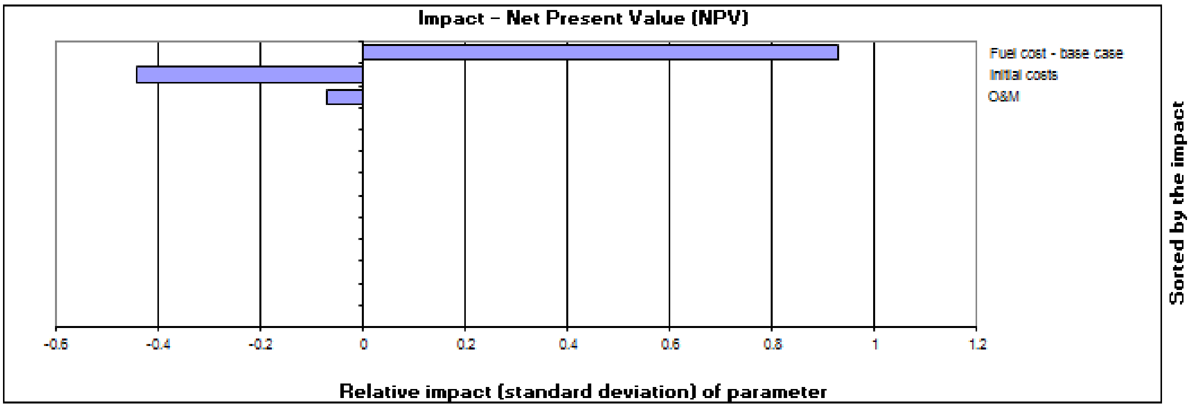


Table 16

Median	BDT	59,366
Level of risk	%	20.0%
Minimum within level of confidence	BDT	49,230
Maximum within level of confidence	BDT	70,243

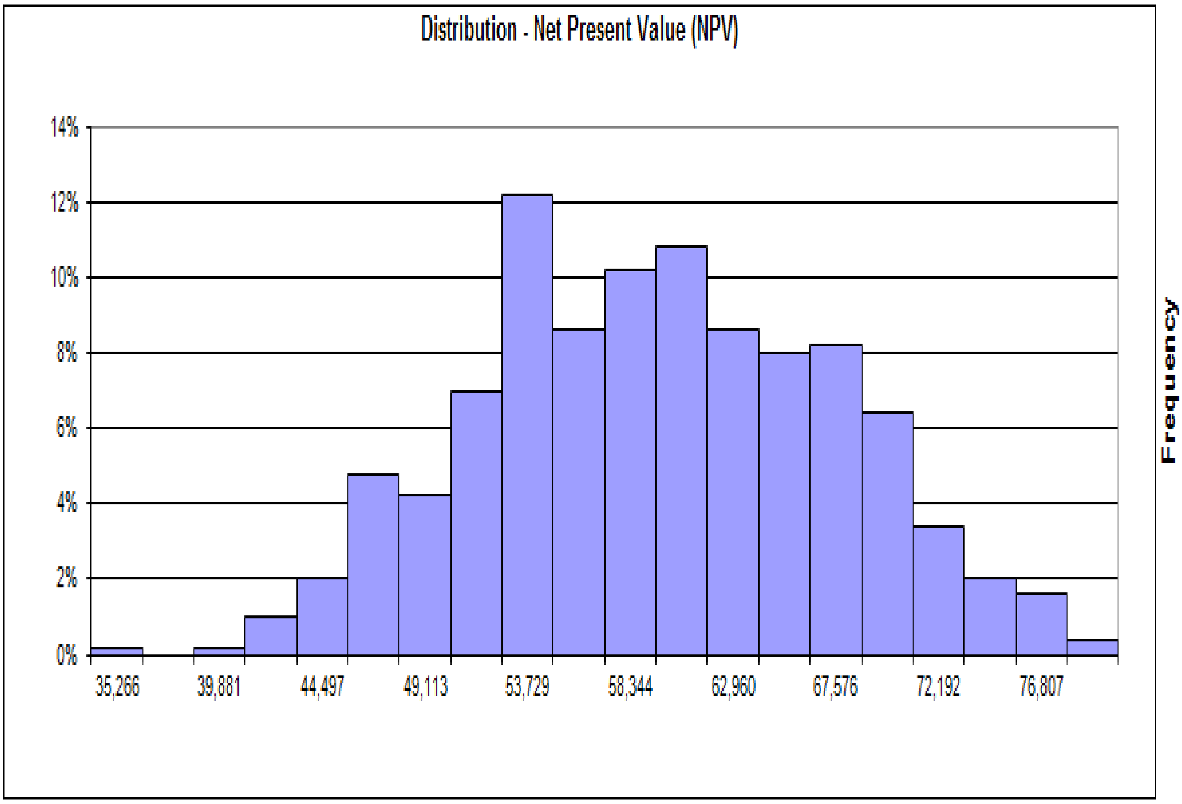


Table 17

The above chart represents the range of values of NPV (49730-70243Tk), for which our project has the viability.

Conclusion:

From our analysis it has been identified that solar irrigation system is feasible for small pumps for surface water irrigation .Well, no conclusion can be drawn if this solar system idea is also feasible for larger capacity of pump or submersible pump. It is also seen that after 13 years the project seems to become a way of income to the poor as it generates cash flows. The project would have been more profitable and feasible if the same system integral with a battery could be used to generate electricity during rainy season ,as there is plenty of natural water for irrigation.

Bibliography:

[1] =The economic value of water in the Ganges-Brahmaputra-Meghna river basin, Nasima Tanveer Chowdhury

[2] =SWERA project ,2007