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An Economic Feasibility Study of Solar and Diesel Water Pumping Systems for Irrigation in Ethiopia: A Case Study of Kombolcha, Wollo

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ABSTRACT

This paper presents the study of economic feasibility analysis of solar water pumping systems compared to diesel-based water pumping systems. The study is highly essential for countries with agriculture-based economies like Ethiopia. The main disadvantages of the diesel-based water pumping system are high fuel cost and abnormal CO_2 emission around 2.3 kg/lit to the atmosphere in Ethiopia. These drawbacks can be solved by a solar water pumping system due to mark-able solar potential in many parts of the country. The total expenditure of both systems was calculated. In addition, the total revenue of both systems was estimated. With the suitable cash inflows and cash outflows the method of Profitability Index has been used in this study. Furthermore, the salvage value and life cycle cost of both systems were assessed. The Profitability Index of the solar water pumping system was found to be 3.2, whereas the diesel-based water pumping system was only 0.06. The life cycle cost of the solar water pumping system was estimated to be 218,324.3 ETB (Ethiopia Birr), whereas the diesel-based water pumping system was only 1,127,116 ETB. From these results, it can be concluded that the solar water pumping system is the best choice for installation.

Keywords: Agriculture, Diesel Based Water Pump, Economic Analysis, Renewable Energy, Solar Water Pump.

1. INTRODUCTION

Energy is the most fundamental necessity of every person on the earth and it is now more important than ever. The energy produced obtained from fossil fuels is widely used but it is non-renewable and environmental non friendly due to greenhouse effects caused by the emission of harmful greenhouse gases including CO_2, CO, S, NOx, and others. These gases not only hurt people by causing heart problems and skin conditions, but they also contribute to global warming by releasing carbon dioxide into the environment. Therefore, utilizing renewable energy sources, especially photovoltaic (PV), wind, solar thermal, and biomass sources is essential for energy generation. One of these, PV produces direct current from solar radiation making it very effective in rural places. Based on actual requirements and advantages for powering irrigation pump sets for rural lighting and electrification, concentrated power generation, urban applications, highway lighting, etc., there is huge potential for off-grid deployment in Kombolcha, Ethiopia since the average solar radiation in this area is above 5.5KWh/day-m2 as presented in Figure 1 and Table 1.1.

In the 1970s, the first solar-powered pumps were constructed. However, due to the high cost of solar panels, it was not feasible for agricultural use until 2009. When the cost of solar panels began to fall dramatically, solar technology became more viable for agricultural use. It begins to use this resource for water pumping, energy production, food preparation, and climate change around the world as a result of consistently lowering its prices. Many countries have begun to create solar water pumping system plans to speed their implementation due to cost reductions and increased awareness of the potential benefits of this technology [1].

Currently, some developing countries have progressed agriculture beyond just being a local food self-sufficient activity. Recently, agriculture is playing a key role in the social and economic development of many communities in the world. Agriculture, like other activities, is currently attempting to incorporate sustainability actions, including the reduction in energy consumption, the diminishment of environmental impact, and the preservation of natural resources, such as water and soil [2].

Many scholars have conducted cost-benefit comparison of diesel versus solar-energy-derived water pumping using various approaches. Based on the design, investment, and yearly return, AmritKarki and Sunil Prasad Lohan developed a techno-economic analysis of solar water pumping systems. The discounted payback period was nine years, which is within the system's lifetime according to the reports. Other economic criteria were examined, such as the 1.6 benefit-cost ratios and the 18.15 percent internal rate of return [2].

D.C Gokhale conducted a research on the importance of solar-powered agriculture pumps and the technology behind them. The findings demonstrated that solar-powered agriculture has a larger initial investment, more reliable, environmentally benign and requires very little maintenance. These are the major advantages of solar-powered agriculture [4].

Rosa J. Chilundo conducted research on solar water pumping system design and performance5. An extensive literature review was made in this article on the design and performance of solar technology for water pumping as well as the optimal transition viewpoint for developing countries' energy demands [5].

Senol et al. investigated a mobile PV-powered water pump system for irrigation of a 0.5 hectare (5000 m2) apple orchard in Turkey. Irrigation of the apple orchard takes place from May to October, with a daily water requirement of 17 m3/day that meets within three days of pumping each week. For a total dynamic head (TDH) of 20 m, a PV system with an angle of 22degreesand a power of 460 kW was examined [6].

Irrigation access is under pin the global food and livelihood security which is deemed critical to sustainable agricultural growth and economic development. Sustainable agriculture is central in achieving many of the sustainable development goals including poverty alleviation, food security, livelihood security and sustainable ecosystems [7].

Water pumping devices obtained from solar and wind energy was studied by Javier Cuellar et al. as a cost-effective alternative for agricultural irrigation [7]. The findings suggested that pumping systems based on renewable energy (wind and solar) can supply the irrigation water demands of small farmers in Northern Colombia. Even when no capital investment is required, diesel based water pumping systems are the least cost-effective since it consumes a fuel.

D C Gokhale et al. reviewed different articles on solar-powered agriculture pumps and its economic Feasibility. The solar-powered pumping system with brushless direct current (BLDC) motor is a cost effective solution in the long run. Though the initial investment is high, Government of India is supporting the farmers by providing subsidies. This system also has the potential to replace fuel-operated and electrical pumps; thereby providing a sustainable solution for meeting the irrigation requirements of crops [9]. Ndeulita Naukushu et al. conducted research on replacing diesel with solar PV. An increasing global population has brought with it social ills and food insecurity. Due to these social problems, it has become increasingly important for farmers to innovate how they conduct farming activities in a way that allows them to produce more and better crop yields. Their findings from the literature review revealed that solar irrigation systems are more economically and environmentally feasible than diesel-powered systems and other conventional irrigation systems since solar systems have low maintenance costs, low operation costs and no fuel costs [10]. This literature indicates the economical drawbacks of diesel water pumping systems due to the increasing diesel price globally from time to time. So, the use of a diesel based water pumping system is not profitable for the farmer especially in developing countries. The economic growth of a developing country such as Ethiopia is purely dependent on agriculture. If the alternative to the diesel pump is suggested cultivation, the economic growth will be increased hugely. The use of profitable and eco-friendly alternative energy sources is one of the best solutions. Out of the various alternative energy sources, solar energy-based pumping systems are discussed in the present paper due to its high energy potential. Furthermore, such a solar-based agriculture system will certainly improve farmers' living standards. But still, diesel based water pumping is applicable in every part of the country for irrigation purposes. This technology has a high running cost due to high fuel consumption. In addition, the diesel based water pumping system pollutes the environment by emitting carbon dioxide [11].

CO2 emission of diesel (change this word)to be 2.3 kg/lit [12]. Approximately, greenhouse gases (GHG) emissions from fossil fuels in Ethiopia were 9.54 million tons in 2015 [13]. This implies that, in 2015, a $5 per ton price on emissions, based on the carbon content of fuels, would have raised $47.7 million and a $3 price on carbon would have raised $286 million. In our policy scenarios, with the price on carbon rising to $30/ton in 2030, total revenue from the carbon tax can be as high as $800 million in that year, depending on the scenario [14].

The continuous depletion of fossil fuel reserves and growing awareness of their environmental impact promote the development of more sustainable energy supply options. These issues have triggered the researchers to find sustainable sources all over the world [15].

Therefore, due to the fossil fuel resources depletion and their great share in environmental pollution and other issues many countries and researchers are looking for green energy resources based on each region's potential. So far, many kinds of renewable energy sources such as solar, wind, geothermal and others are utilized for power generation to minimize the above stated problems [16].

In this study, it is found that the essentialities of introducing solar water pumping systems to the community of Ethiopia. In the present paper the advantage of the solar water pumping system over existing conventional diesel based water pumping systems is presented.

2. MATERIALS AND METHODS

2.1 Description of the study area and data collection for the proposed systems

The project is located in Kalu Woreda, near to Kombolcha city and the South Wollo Administration Zone of the Amhara Regional State, Ethiopia as shown in Figure 1. Data presented in table 1 were collected from systematically selected groups of farmers and meteorological sources in order to make the economic analysis of both systems for comparison.

Fig. 1 Google map reference of the study area Kombolcha, Ethiopia [17]

Table 1. Details of solar insolations and water deman for the study area

Parameters	Values
Daily water demand over the selected site(Collected from group of farmers)	360 m3/day (0.25 m3/min)
Operating time of the pumping system Collected from group of farmers)	12 days/year @ 6 hour/day for two crop seasons;
Farmer's area used for cultivation.	5000 m2 (0.5 hectare)
Fuel consumption for diesel water pumping system (Collected from group of farmers)	200 letter/year for 12 days/year and it is also for two crop seasons
Current price of fuel (diesel) as per financial year 2021 (Collected from sources of market)	25 ETB/litter
Average solar radiation and peak sunshine hours [17].	5.5 kWh/day-m2 and 5.5 sun shine hours/day under Standard Test Conditions (STC)

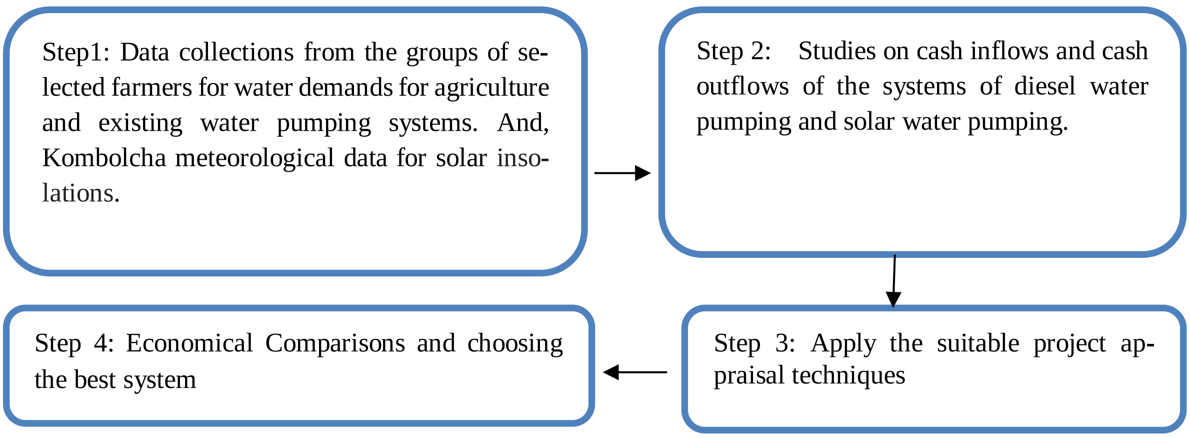

Fig. 2 Systematic representation of the research methodology used in the study

The first task of this study was collecting the necessary data from the selected study area. Geographical, technical, and economic data were collected related to the existing diesel based water pumping and solar-driven water pumping systems in the study area, Kombolcha, Ethiopia.

2.2 Estimation of cash outflows and inflows of the two systems

As part of the study, costs of the installation, fuel, operation and maintenance of both diesel and solar water pumping systems were estimated. Cash inflow (in the form of revenue and the system's end value) and cash outflows (investment and loans taken from the financial institutions) of the project was forecasted based on the present realistic assumptions as it explained below:

2.2.1 Estimation of cash outflows for the diesel based water pumping system

During the study period made in the year 2021, the investment cost of a diesel based water pumping system was 27,000 ETB for pumping water 360 m3/day, which is required to supply for irrigating 0.5 hectare. The pump replacement is essential for every 10 years due to wear and tear. At the inflation rate 5% per year, the replacement cost will become 43,980 ETB. In the 20 years period, the total installation cost will become 70,980 ETB.

Estimation of operator wages: The operator of the diesel based water pumping system during drought periods operates the machine maximum for 12 day in a year. The wages of the operator from the survey is considered 500 ETB/day. Therefore, the wages of the operator in a year will become 6000 ETB.

Estimation of maintenance cost: The annual maintenance cost is the sum of operator wages and pump maintenance. The pump maintenance cost for both crop seasons(summer and winter) is considered to be 20% of the total wages (Misrak Girma, 30 June 2015).Therefore, pump maintenance cost will become 20% of wages i.e, 20% of 6,000 ETB. It becomes 1200 ETB. Then, to all expenditure on maintenance will thus become 7200 ETB/year.

Estimation of fuel cost: As per market value in 2021, the cost of Diesel was 23.75 ETB / liter. As per the survey report collected from a group of farmers the pump is expected to operate for 12 days in a year. During the 12 days, the survey report revealed the fuel consumption was 200 liters. As per above, annual present fuel cost (PFC) will become 4,750 ETB.

Estimation of fuel cost for 20 years life time of the pump: The fuel cost for a certain period can be calculated based on the relation

$$\mathrm{FC} = P_{FC}(1+i)^n \qquad (1)$$

In equation 1, PFC is the present fuel cost, and n is the life time of the pump i.e., 20 years, and, 'i' is the inflation rate i.e, 15.8 % [12]. A fuel cost escalation of 15.8% has been assumed but the fact remains that this is an indeterminable parameter as it depends on oil reserves, conflict in oil producing countries and exchange rate. Therefore, cash outflows of the proposed system are estimated in Table 2.

The total cash outflow is not only the MC. It also includes the installation cost, the pump replacement cost, and fuel cost (624,446.70 ETB for 20 years as stated in Table 2). The cost of the diesel pump 3.7 kW capacity is 27,000 ETB. Due to 10 year life time the pump replacement is essential and its cost is 43,980.20 ETB (it includes the inflation rate). Therefore, the total cash outflow including MC, it becomes 1,130,369.90 ETB.

2.2.2 Estimation of cash inflow for the diesel based water pumping system in comparison with solar pumping system

The initial investment for solar pump and diesel based water pumping system are respectively 93,600 ETB (as per section C) and 31,750 ETB with respect to Table 2 respectively. The difference of the above will become the return on the diesel based water pumping system and can be considered as its cash inflow.

Table 1. Consolidation of cash outflows for diesel based water pumping system for 20 Years

Time, in years (i)	FC (ETB) (ii)	Cash outflow in terms of MC, in ETB (iii)	Total FC+ MC, in ETB (iv = ii+iii)	Cumulative Cash out-flow (FC&MC) in, ETB , (v) (v) = $\sum_{i=0}^{20}(iv)$
0	4750	First pump is installed.	4750	4750
1	5500.5	7920	13420.5	18170.5
2	6369.6	8712	15081.6	33252.1
3	7376	9583.2	16959.2	50211.3
4	8541.4	10541.5	19082.9	69294.2
5	9890.9	11595.7	21486.6	90780.8
6	11453.7	12755.2	24208.9	114989.7
7	13263.4	14030.8	27294.2	142283.9
8	15359	15433.8	30792.8	173076.7
9	17785.7	16977.2	34762.9	207839.6
10	20595.8	Replaced the first pump.	20595.8	228435.4
11	23850	20542.4	44392.4	272827.8
12	27618.3	22596.7	50215	323042.8
13	31981.9	24856.4	56838.3	379881.1
14	37035.1	27342	64377.1	444258.2
15	42886.6	30076.2	72962.8	517221
16	49662.7	33083.8	82746.5	599967.5
17	57509.4	36392.2	93901.6	693869.1
18	66595.9	40031.4	106627.3	800496.4
19	77118.1	44034.5	121152.6	921649
20	89,302.70	48,438.00	137740.7	1059390
	$\sum_{i=0}^{20}(FC_i)$. = 624,446.7	$\sum_{i=1}^{20}(MC_i)$. = 434,943	$\sum_{i=0}^{20}(FC_i + MC_i)$. = 1059390	Cumulative FC&MC = 1059390

FC: Fuel cost; MC: Maintenance cost; RC Replacement Cost; TC: Total Cost; ETB: Ethiopia Birr

Thus, 61,850 ETB were found as cumulative income/inflow throughout the project duration. But, the returns during subsequent years after installation of the diesel based water pumping system were neglected. The returns after the installation of the solar pump were expected to be present, since it involves no fuel cost, no replacement cost and very less maintenance cost.

2.2.3 Estimation of cash outflow for the solar water pumping system

The market price as per year 2021 for 1 watt capacity PV installation was 20 ETB. But, the PV array is designed with 8 numbers of panels, of each capacity 315 W. This array is suitable for lifting 360 m3/day of water for irrigation. Thus, the array's power generation becomes 2520 W. The installation cost of PV array as per market price was 50,400 ETB. Apart from the PV array; the solar water pump, its controller, storage battery, and valve fittings are essential. Their market value in the same year was 43,200 ETB. Therefore, the total installation cost of solar water pumping becomes 93,600 ETB.

Estimation of Cost for Wages: Similar to the diesel based water pumping system, the wages for operating the solar pump system can be considered 6000 ETB/year for two crop seasons.

Estimation of Maintenance Cost: A little maintenance is required for cleaning the surface of the PV panel. Its cost is considered to be 2 % of Cost for wages for the two crop seasons in a year. Therefore, the annual maintenance cost for this system becomes 120 ETB / year. Thus, the sum of cost for wages and maintenance of the PV system becomes 6,120 ETB/year. Whereas, these costs for the diesel based water system was 7200 ETB/year as per previous discussion mentioned in section A. Therefore, the savings on maintenance, which is highly significant, becomes 1080 ETB/year. The cash outflow of the proposed PV pumping system is estimated and tabulated in table 3. The cash flow of the investment project is forecasted based on the present realistic assumptions.

Table 3. Consolidation of the cash outflow of solar water pumping system

Time, in years (i)	Cash outflow in terms of MC, in ETB (ii)	Cumulative cash outflow (MC), in ETB (iii) (iii) = $\sum_{i=0}^{20}(ii)$
0	---	
1	6181.2	6181.2
2	6243	12424.2
3	6305.4	18729.6
4	6368.5	25098.1
5	6432.2	31530.3
6	6496.5	38026.8
7	6561.5	44588.3
8	6627.1	51215.4
9	6693.4	57908.8
10	6760.3	64669.1
11	6827.9	71497
12	6896.2	78393.2
13	6965.1	85358.3
14	7034.8	92393.1
15	7105.1	99498.2
16	7176.2	106674.4
17	7247.9	113922.3
18	7320.4	121242.7
19	7393.6	128636.3
20	7467.6	136103.9
	= $\sum_{i=1}^{20}(MC_i)$ 136,103.90	Cumulative MC = 136,103.90

In the above, the initial investment cost was not considered to obtain the total cash outflows. The investment cost is a little high for installation of solar water pumping system and found 93,600 ETB. It includes the solar panel cost of capacity 2520 W and 3.7kWpump capacity. Therefore, along with cumulative MC, the total cash outflow becomes 136,103.9 ETB.

2.2.4 Estimation of cash inflow for the solar water pumping system

Solar pumping system does not involve fuel. Therefore, diesel cost in the diesel based water pumping system shall become the return for this system. Furthermore, the solar pump does not require replacement. Since, its life time is 20 years. Therefore, the returns for the proposed solar water pumping system were high and very significant. The cash inflows of this system are estimated and presented in Table 4.

Solar water pumping systems do not require pump's replacement. But, DWPS required the pump replacement. Therefore, the concerned replacement cost 43980.2 ETB shall become the additional revenue to SWPS system. Therefore, the total returns were found to be 733,668.5 ETB.

Table 4. Consolidation of cash inflows of solar water pumping system for 20 years

Time, in years (i)	Revenue occurrence by saving the fuel, in ETB (ii)	Revenue occurrence by minimizing MC, in ETB (iii)	Total revenue in the form of fuel savings and MC, in ETB (iv) = (ii) + (iii)	Cumulative Revenue / Cash inflow, inETB (v) = $\sum_{i=0}^{20}(iv)$
0	4750.0	0.0	4750	4750
1	5500.5	1188.0	6688.5	11438.5
2	6369.6	1306.8	7676.4	19114.9
3	7376.0	1437.5	8813.5	27928.4
4	8541.4	1581.2	10122.6	38051
5	9890.9	1739.4	11630.3	49681.3
6	11453.7	1913.3	13367	63048.3
7	13263.4	2104.6	15368	78416.3
8	15359.0	2315.1	17674	96090.3
9	17785.7	2546.6	20332.3	116422.6
10	20595.8	--	20595.8	137018.4
11	23850.0	3081.4	26931.3	163949.7
12	27618.3	3389.5	31007.8	194957.5
13	31981.9	3728.5	35710.4	230667.9
14	37035.1	4101.3	41136.4	271804.3
15	42886.6	4511.4	47398.1	319202.4
16	49662.7	4962.6	54625.3	373827.7
17	57509.4	5458.8	62968.3	436796
18	66595.9	6004.7	72600.6	509396.6
19	77118.1	6605.2	83723.3	593119.9
20	89302.7	7265.7	96568.4	689688.3
	Revenue . $\sum_{i=0}^{20}(FC_i)$. = 624,446.7	Revenue. .$\sum_{i=1}^{20}(MC_i)$ = 65,241.6	Total Revenue. .$\sum_{i=0}^{20}(FC_i + MC_i)$ = 689,688.3	Total Revenue, TR = 689,683.3

2.3 Methods for checking economic feasibility

Commonly, in order to check the economic feasibility of the proposed systems the following methods have been used. They are named Net present value (NPV), Payback Period (PBP), Profitability Index (PI), Life Cycle Cost Analysis (LCCA).

2.3.1 Determination of annual NPV

As presented in table no. 3 and table no. 4, the cash inflows and cash outflows were estimated. Therefore, the NPV of two systems can be determined using the equation (2). As it is known, NPV is the most acceptable measure for appraisal technique for a project.

Mathematically:

$$NPV = \sum_{t=0}^{20}[B_t - C_t] = [B_0 - C_0] + [B_1 - C_1] + [B_2 - C_2] + \cdots + [B_{20} - C_{20}] \quad (2)$$

Where, Btand Ct are cash inflow and cash outflow respectively in‘t’ years and‘t’ varies from 0thyear to 20th year [18].

Table 5. Estimation of net present value of two systems

Finding NPV of Solar Water Pumping System				Finding NPV of Diesel Based Water Pumping System			
Timein 't' years (i)	B_t , Cash inflow from table no. 4, in ETB (ii)	C_t , Cash outflow from table no. 3, in ETB (iii)	B_t -C_t in ETB, (iv (iv)= (ii)- (iii)	Time, in 't' years (v)	B_t, Cash inflow from Section B, in ETB (vi)	C_t ,,Cash outflow from table no.2, in ETB (vii)	B_t-C_t in ETB (viii), (viii) = (vi)- (vii)
0	4750	93,600	-88,850	0	61,850	31750	30,100
1	6688.5	6181.2	507	1	0	13420.5	-13,421
2	7676.4	6243	1,433	2	0	15081.6	-15,082
3	8813.5	6305.4	2,508	3	0	16959.2	-16,959
4	10122.6	6368.5	3,754	4	0	19082.9	-19,083
5	11630.3	6432.2	5,198	5	0	21486.6	-21,487
6	13367	6496.5	6,871	6	0	24208.9	-24,209
7	15368	6561.5	8,807	7	0	27294.1	-27,294
8	17674	6627.1	11,047	8	0	30792.8	-30,793
9	20332.3	6693.4	13,639	9	0	34762.9	-34,763
10	64576	6760.3	57,816	10	0	64576	-64,576
11	26931.3	6827.9	20,103	11	0	44392.4	-44,392
12	31007.8	6896.2	24,112	12	0	50214.9	-50,215
13	35710.4	6965.1	28,745	13	0	56838.3	-56,838
14	41136.4	7034.8	34,102	14	0	64377.1	-64,377
15	47398.1	7105.1	40,293	15	0	72962.8	-72,963
16	54625.3	7176.2	47,449	16	0	82746.5	-82,747
17	62968.3	7247.9	55,720	17	0	93901.6	-93,902
18	72600.6	7320.4	65,280	18	0	106627.3	-106,627
19	83723.3	7393.6	76,330	19	0	121152.6	-121,153
20	96568.4	7467.6	89,101	20	0	137,740.70	-137,741
	.=$\sum_{i=0}^{20}(C_{if})$ 733,668.5	.$\sum_{i=0}^{20}(C_{of})$ =229,704	NPV = 503,965		.$\sum_{i=0}^{20}(C_{if})$ = 61,850	.$\sum_{i=0}^{20}(C_{of})$ = 1,130,370	.NPV = -1068,5220

NPV: Net Present Value; $\sum_{i=0}^{20}(C_{if})$: Total Cash inflow; $\sum_{i=0}^{20}(C_{of})$: Total Cash outflow.

From the data presented in Table 5, the NPV of the solar PI is the ratio of cumulative present value of all cash inflows to cumulative present value of all cash outflows of

2.3.2 Determination of profitability index (PI) of two systems

a project [18]. It indicates the capacity of profit generation water pumping system is positive and found extremely higher than the diesel based water pumping system.

$$PI = \frac{\text{Cumulative cash inflow}}{\text{Cumulative cash out flow}} \quad (3$$

Table 2. Estimation of salvage value of the two systems

SV of Solar water pumping system					SV of Diesel based water pumping system			
Time, in 't' years (i)	CC from table no. 3, in ETB (ii)	Depreciation factor at @ 10%* (iii)	SV in ETB (iv) (iv) = (ii)×(iii)		Time, in 't' years (i)	CC from table no. 2, in ETB (ii)	Depreciation factor at @ 10%* (iii)	SV in ETB (iv) (iv) = (ii)×(iii)
0	93600	1.0	93600.0		0	27000	1.0	27000.0
1	93600	0.9	84240.0		1	27000	0.7	19170.0
2	93600	0.8	75816.0		2	27000	0.5	13610.7
3	93600	0.7	68234.4		3	27000	0.4	9663.6
4	93600	0.7	61411.0		4	27000	0.3	6861.2
5	93600	0.6	55269.9		5	27000	0.2	4871.4
6	93600	0.5	49742.9		6	27000	0.1	3458.7
7	93600	0.5	44768.6		7	27000	0.1	2455.7
8	93600	0.4	40291.7		8	27000	0.1	1743.5
9	93600	0.4	36262.6		9	27000	0.0	1237.9 (SV of original pump)
10	93600	0.3	32636.3		10	43980 (Replacement Cost)	1.0	43980.0
11	93600	0.3	29372.7		1	43980	0.7	31225.8
12	93600	0.3	26435.4		2	43980	0.5	22170.3
13	93600	0.3	23791.9		3	43980	0.4	15740.9
14	93600	0.2	21412.7		4	43980	0.3	11176.1
15	93600	0.2	19271.4		5	43980	0.2	7935.0
16	93600	0.2	17344.3		6	43980	0.1	5633.9
17	93600	0.2	15609.8		7	43980	0.1	4000.0
18	93600	0.2	14048.9		8	43980	0.1	2840.0
19	93600	0.1	12644.0		9	43980	0.0	2016.4 (SV of replaced pump)
20	93600	0.1	11,379.6		10	SV of original & replaced diesel pumps)		3,254.3

(*Source for depreciation rate: 'ATO Depreciation rate'; https://www.depreciationrates.net.au/pu

From Table 5 , For solar water pumping system:

$$PI = \frac{733668.5}{229704} = 3.194 \approx 3.2$$

For diesel water pumping system:

$$PI = \frac{66,600}{1130370} = 0.0589 \approx 0.06$$

From the results of equation 3, the PI of the solar water pumping system is much higher when compared to diesel based water pumping system. Therefore, the solar water pumping system can be selected for the installation.

2.3.3 Estimation of payback period (PBP) of the two systems

By definition, the PBP is the number of years that it takes to recover the investment[19]. It will be estimated by adding net cash flow in the project until the cumulative net cash flow equal to initial investment.

$$PBP = \frac{\text{Capital Cost of the Project}}{\text{Net Annual Cash Inflow}} \quad (4)$$

The actual capital cost for the solar pumping system is obtained by subtracting the solar pumps initial cost (93,600 ETB) and the diesel pump's replacement cost (43,980.2 ETB). Since, solar pumping system does not required pump replacement during the first twenty years. The net annual cash inflow for this system is the sum of fuel saving cost (4,750 ETB) and savings in MC (1,080 ETB).

For diesel based water pumping system, no PBP, from table no. 5, NPV is negative.

2.3.4 Estimation of LCC of two systems

LCC is useful for estimating the net expenditure of the two water pumping systems. It is the difference between the total costs of installation, maintenance, running etc, throughout the system's lifetime and its salvage value / end value (H. Bierman, 1993)

Accordingly,

LCC = TC – LCC = (CC + FC + MC + RC) – SV (5)

Where,

CC is the capital cost or installation cost FC is the total fuel cost during system's lifetime

MC is the maintenance cost during system's lifetime

RC is the replacement cost during system's lifetime

SV is the salvage value of the system

The salvage value (SV) of a system or end values of a system is the net amount of money obtainable from the sale of used property [19]. It is estimated using a diminishing balancing method, since a depreciating asset decreases more in the early years of its effective life. It is one of the depreciation appraisal techniques.

Mathematically,

$$SV = CC(1-r)^n \quad (6)$$

In equation 6, r is the depression rate of the asset due to wear and tear, corrosion, accident, and deterioration, during its lifetime and, $(1- r)^n$ is called depreciation factor [20].

3. RESULTS AND DISCUSSION

In this section, the economic feasibility aspects of the two systems were presented from the analysis made in previous sections and compared their results graphically.

Table 7. Cost comparison of the two systems

Type of cost	Cost for solar water pumping system, in ETB	Cost for diesel based water pumping system, in ETB
CC	93,600	27,000
Life Time	20 years	10 Years
Total OC & MC	136,104	434,943
Total FC	None	624,447
Total RC	None	43,980
TC	229,704	1,130,370
SV	11,379.6	3,254.5
LCC	218,324.3	1127,116

The life cycle cost of a solar water pumping system is only 218,324.3 ETB. But, for the diesel based water pumping system, it is very high and found 1127,116 ETB. Therefore, the solar water pumping system is recommended for the installation. Therefore, it is proved that solar powered irrigation is economically feasible.

3.1 Cost Comparison of the two systems

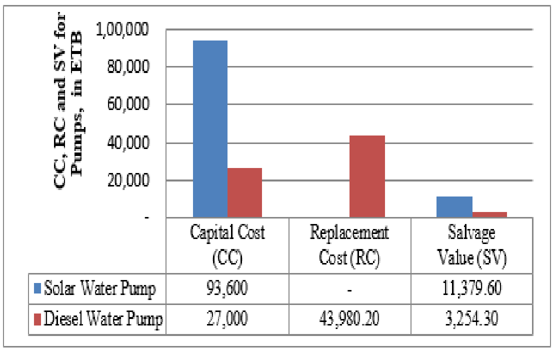

Fig.3 Comparison of the capital cost, replacement cost and salvage value of the two pumping systems

The graphical representation in Figure 3 and Figure 4 describes the cost comparisons of the two pumping systems based on data presented in Table 2.

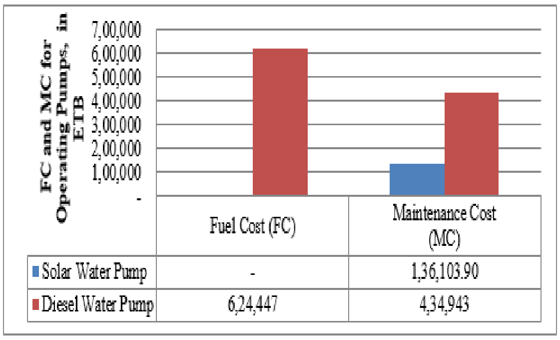

Fig.4 Comparison of fuel cost, maintenance cost of the two pumping systems

Figure 3 and Figure 4 show that the solar water pumping system has the advantage of no replacement cost, since its lifetime is nearly 20 years. Whereas, the diesel based water pumping system needs to be replaced after 10 years. Another advantage of the solar pump is its high salvage value. The farmer can get a massive return after its lifetime. The additional advantage of a solar pump is no fuel cost. Because it purely dependents on solar radiation. Whereas, the diesel based water pumping system requires diesel as fuel and is costly. Furthermore, the maintenance cost for solar pumps is less. It is significantly high for diesel based water pumping systems due to its high operating temperatures and various energy conversions. The only disadvantage of the solar water pumping system is its high installation cost for pumping the same volume flow rates.

3.2 Total cost and life cycle cost of the two pumping systems

Figure 5 shows that the total cost of the diesel based water pumping system is higher than the solar water pumping system. It is due to more fuel cost, maintenance cost, and replacement cost. Therefore, diesel based pump is less suited for the installation. It implies, the LCC of the solar water pumping system is considerably less, and therefore, it is best suited for the installation.

3.3 Break Even Point (BEP) Solar Water Pumping System and its Analysis

BEP of any system indicates no profit and no loss. The intersection of the total cost line and the total revenue line is the BEP of that system and shown in Figure 6. In this case, the cost is taken on the ordinate in ETB, and the lifetime of the pumping system is taken on the abscissa in years.

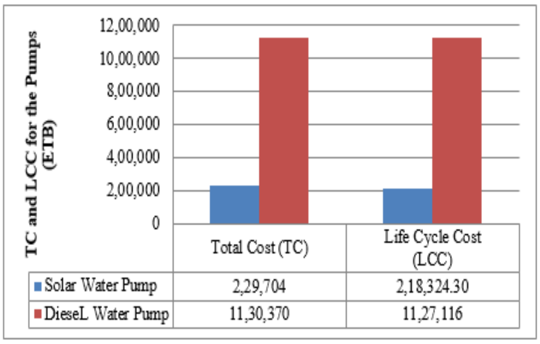

Fig.5 Total cost and life cycle cost of solar and diesel based water pumping system

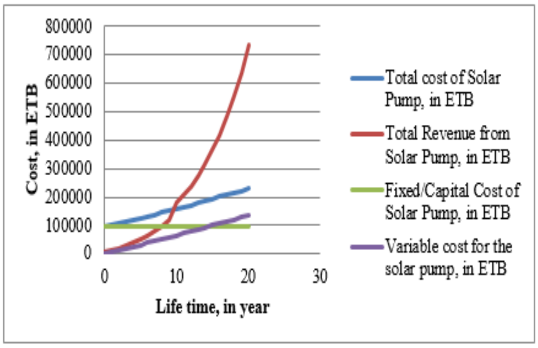

Fig.6 Graphical representation of breakeven point for solar water pumping system

In this study, the cumulative cash outflow can be considered as the total variable cost of the system. Similarly, cumulative cash inflow can be considered as the total revenue of the system. In order to indicate BEP, the particulars of expenditures and revenues were used and show in Figure 6.

As shown in Figure 6, the BEP is found on X axis at nine years and six months and it coincides with the payback period of the system. And, the results indicate that the total expenditure incurred over the system can be recovered within this period of time. After this time, the system results in more profits.

4. CONCLUSION

The following conclusions were drawn from the study The diesel based water pump requires 200 liters/year of diesel to supply water to 0.5-hectare land. But, no fuel is required for supplying water by a solar pump. It is a significant saving due to the solar pump. During the 20 years span, the total expenditure for the solar water pumping system was only 229,074 ETB, whereas for the diesel based water pumping system it was high and found 1130,370 ETB. Excluding the salvage value, the LCC of the solar water pumping system was found. For the solar water pumping system, it was only 218,324.3 ETB. But, for the diesel based water pumping system, it was very high and determined to be 1127,087.6 ETB. The system with high PI results in massive returns. In the present analysis, the PI of the solar water pumping system was 3.2, whereas for the diesel based water pumping system it was only 0.06.The PBP of the solar water pumping system was nine years and six months. From the BEP analysis, it was found that the system starts generating profits at the same time after the installation. Considering the above-stated advantages, technical and economic feasibility the solar water pumping system is the best choice for the installation when compared to a diesel water pumping system working under the same operating conditions.

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-We hereby confirm that all the Figures and Tables in the manuscript are ours. Besides, the Figures and images, which are not ours, have been given the permission for re-publication attached with the manuscript.

AUTHOR CONTRIBUTIONS

This work was carried out in collaboration between all authors. Mr. Hailemariam Berhanu generated the idea, diagnosis the cases then collected the data, wrote, and doing the design analysis with interpretation. Mr. Fiseha Bogale edited the manuscript with revision and proofreading. Mr Alemshet Abebe drafted the manuscript with revision idea. All authors read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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