International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133; Print ISSN: 2664-7125; Impact Factor: RJIF 5.28
Received: 28-10-2020; Accepted: 29-11-2020; Published: 06-12-2020
Volume 2; Issue 4; 2020; Page No. 564-566

A farm centric explorative study on economic feasibility of solar water pump installation using life cycle cost approach in Coimbatore district of Tamil Nadu

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Abstract
Irrigation is the most important input in agricultural production process. Huge investments are made for creation and maintenance of irrigation infrastructure. Hence water use efficiency is an important attribute. The different energy sources for pumping water assumes economic importance not only for the farmers but to the country as a whole. An attempt is made in this paper to understand the life cycle cost of different pumping systems for Solar Photo Voltaic pump system, Electric driven pump and diesel driven pump over the life period. Comparative evaluation of the life cycle costs of the three alternate systems for water pumping indicated better economic feasibility of Solar Water Pumps compared to the Electricity and Diesel based water pumps. On the other hand, the ease of maintenance and longer life period of the solar water pumps are the major reasons for their promotion and adoption apart from being a source of renewable energy. The analysis also indicated that the solar water pumps are economically feasible even without the subsidy extended by the Government. The major issue in adoption of solar technology is higher initial capital investment compared to the other two options and this issue needs to be addressed by the Government through ease of credit with long term repayment options at a subsidized rate of interest.

Keywords: Economic feasibility, life cycle cost, solar photo voltaic system, investment

Introduction
Ensuring effective irrigation for agriculture is necessary as it will have an impact on agricultural productivity and food security of the nation. In order to raise productivity and to cater to the needs of ever-growing population and enhance the profitability and competitiveness of farm produce, focus should be made on optimizing the energy usage and efficient use of available water resources. Pumping systems play a crucial role in provision of optimized solutions for energy and water use. Many studies have pointed out that energy for operating irrigation pumps is the highest cost driver in the farming systems widely prevalent in the country. Usage of best energy management practices are expected to result in cost reduction and optimize the energy use.
Pumping systems can be operated using both renewable and non-renewable energy sources. Pumping water from ground level using conventionally powered pumps namely diesel and electricity pumps use resources like fossil fuels or electricity. In India around 190 lakhs of Electric pumps and 70 lakhs of diesel pumps are used for pumping water from the ground level (KPMG, 2014) [7]. In India, more than 40,000 lakhs litres of diesel is consumed and constitute 3.1 per cent of national diesel consumption and 85 million tonnes of coal is used for lifting water for irrigation. Many states in India are providing free electricity to farming community for pumping the water from ground level. Due to frequent power cut and rising cost of fuel to run the diesel pumps, the farmers are moving towards alternate source of renewable energy for agricultural purposes. Under these circumstances the research study was conceived to understand the economic feasibility of installing solar photo voltaic water pumps vis-a-vis the diesel and electric pump systems used for irrigation in Coimbatore district of Tamil Nadu using Life Cycle Cost approach.

Review of Past Studies
Some of the related studies conducted regarding the focus area of the study are reviewed and presented.
Al-Karaghouli and Kazmerski (2010) [1] defined life cycle cost as the total cost involved in installing and operating a system over its life span. Leckner and Zmeureanu (2011) [3] defined life cycle cost analysis as the total economics over the life period of the product. Sako *et al*. (2011) [6] analyzed the most cost-effective source among photo voltaic, diesel and electricity for rural areas using life cycle cost analysis. The results revealed that diesel generator became more expensive after six years whereas photovoltaic was more expensive in the beginning and later on there was low/ zero maintenance cost. The author reported that grid required 50 kWh/day to operate whereas photovoltaic did not require any external source of energy. The results showed that photovoltaic system was most cost-effective for usage in remote areas rather than the grid and diesel generator. Narale *et al*. (2013) [5] used the life cycle cost analysis for solar PV system (SPV) and diesel water pumping system for irrigation in 0.65 hectare of banana crop. The daily water requirement for banana crop was estimated to be 9720 litres with the total sun shine hours of 6.02 hours per day. Life cycle cost analysis of SPVs were found to be

Rs.138958.17 whereas for diesel engine it was found to be Rs.760029.00 and concluded that solar water pumping system is more economical than diesel pumping system. According to Alves *et al*. (2014) lifting water using solar energy were found to incur lower total cost and higher capital cost whereas with diesel engine there was very minimal capital cost and higher total cost. It was found that lifting water through solar energy was economically viable compared to diesel pumping system. The pumping cost also found to be lower only in solar pumping system when compared with pumping cost of diesel engine which was the deciding factor in selecting the type of pump for irrigation.

Heralova (2014) stated life cycle costing was the method which is used to calculate all the costs that are related to constructing, operating and maintaining a project over a particular period of time.

Narale *et al*. (2014) [4] used life cycle cost analysis to obtain the economic feasibility of the solar water pumping system. The results revealed that solar pumping was the best method for irrigation in banana cultivation in orchards of Maharashtra.In the present study, life cycle cost analysis was conducted to estimate the economic feasibility of solar photo voltaic , electric pump and diesel pump systems.

Sampling Methodology

Coimbatore district was purposively selected for the study as it is one of the leading districts in installation of solar water pumps in Tamil Nadu state. Information was collected from sixty farmers in ten different blocks of the district that constituted the sample for the study.

Analytical Tool

Life cycle cost analysis (LCCA) is a method of evaluating the total cost of the system. It includes all costs such as acquiring, owning and disposing the equipment. In this study, LCCA was calculated and compared for Solar Photo Voltaic pump system, Electric driven pump and diesel driven pump over the life period. The reasons for calculating LCCA was to determine the cost-effective system. The LCC was calculated using the formula: (Narale *et al*., 2013) [5]

Life Cycle Cost = CC + MC + EC + RC – SC

Table: 1 Explanation for Cost Components Used in Life Cycle Cost Analysis

Capital cost (CC)	It includes all the capital expenses for installation of SPV pumps such as Solar panel, Inverter, Module mounting structure, Earthing and G.I wire cost whereas for diesel and electric pumps the capital expenses includes cost of pumps.
Maintenance cost (MC)	It is the yearly repair and maintenance cost for all the systems (10 percent of the capital cost of the system).
Energy cost (EC)	It is the sum of yearly fuel and electricity cost for electric pump set whereas in SPV system there is no energy cost because of free source of energy.
Replacement cost (RC)	It is the overall replacement of the equipment after the life of the system. In SPV system replacement cost includes cost of replacement is for solar panels, whereas diesel and electric pumps replacement cost includes capital cost of the pumps.
Salvage cost (SC)	It is the net worth of the system after life cycle period. Generally 20 percent of capital cost.

The economic feasibility is the process of determining the financial feasibility of the technology adopted.

Life Cycle Cost Analysis (LCCA)

Life cycle cost analysis estimated the total cost involved in installing and operating a system over its life span. The estimated life span of SPV system, diesel pump and electric pump was considered to be ten years for ease of comparison though the life span would be higher and vary among the systems. The energy cost of the diesel pump is the sum of yearly diesel costs and electricity cost for electric pump set whereas there was no energy cost for SPV system.

Farmers opined that they have been running the electric pump for 12 hours a day in all the 365 days because the ground water is the major source in Coimbatore district. If one 5 HP electric pump runs for one hour, it consumes 3.73 units of electricity, therefore 5 HP pump works for 12 hours consumed 44.76 units per day and 16,337.4 units per year and total of 163374 units over life time. The price per unit of electricity was Rs.6.35 (proxy cost from Tamil Nadu Electricity Board for Economic purpose); therefore, the total electricity cost was estimated as Rs.10.38 lakhs over a life period of ten years.

The details of diesel pump usage among the farmers were collected. In comparison, a 5 HP diesel pump runs for one hour it consumes 1.07 litres of diesel, therefore on an average the pump worked for 7.15 hours and consumed 7.65 litres of diesel per day resulting in diesel consumption of 2295.15 litres per year of 300 days and total of 22951.5 litres over life time. The price per litre of diesel was considered to be Rs.70; therefore, the total diesel cost was estimated as Rs.16.07 lakhs over a life of 10 years.

The capital cost, maintenance cost and replacement cost of solar, diesel and electric pump systems are presented in Table 2.

Table: 2 Capital, Maintenance and Replacement Costs of Alternate Sources of Pumping Systems

S. No	Particulars	Amount(Rs.)
1	Capital cost of SPV (Without subsidy)	3,40,200.00
2	Capital cost of SPV (With subsidy)	34,020.00
3	Capital cost of electric pump	28414.00
4	Capital cost of diesel pump	27048.00
5	Maintenance cost without subsidy (10% of capital cost)	34,020.00
6	Maintenance cost with subsidy (10% of capital cost)	3,402.00
7	Maintenance cost of electric pump (10% of capital cost)	2841.40
8	Maintenance cost of diesel pump (10% of capital cost)	2704.80
9	Replacement cost of SPV (with and without subsidy)	2,17,728.00
10	Replacement cost of electric pump (C.C of pump)	28414.00
11	Replacement cost of diesel pump (C.C of pump)	27048.00

The Life Cycle Cost Analysis was carried out for two different following situations to understand whether the investment made on the solar pumps would be economically feasible under both the following situations.

Situation 1: Solar Photovoltaic System without Government Subsidy

Situation 2: Solar Photovoltaic System with Government Subsidy

Life Cycle Cost Analysis of Alternate Water Pumping Systems

The Life cycle cost (LCC) of 5 HP SPV system (without subsidy), 5 HP Electric Pump set and 5 HP diesel pump set were calculated, and the results are presented in Table 3.

Table: 3 Life Cycle Cost of Solar, Diesel and Electric Pumping Systems

S.No	Particulars	Solar Photo Voltaic		Diesel Pump set	Electric Pump set
		Without Subsidy	With Subsidy		
1	Capital cost (Rs.)	3,40,200.00	34,020.00	27,048.00	28,414.00
2	Maintenance cost (Rs.)	34,020.00	34,020.00	2,704.80	2,841.40
3	Replacement cost (Rs.)	2,17,728.00	2,17,728.00	27,048.00	28,414.00
4	Energy/Fuel cost (Rs.)	0.00	0.00	16,06,605.00	10,37,429.90
Total cost (Rs.)		5,91,948.00	2,85,768.00	16,63,405.80	10,97,099.30
5	Salvage value (20% of Capital Cost)	68,040.00	6,804.00	5,409.60	5,682.80
Life cycle cost (Rs.)		5,23,908.00	2,78,964.00	16,57,996.20	10,91,416.50
Life cycle cost (Rs. In lakhs)		5.24	2.79	16.58	10.91

From Table 3, it could be inferred that the total cost of SPV system with life span of 10 years (without subsidy) was found to be Rs.5,91,948.00 compared to electric pump set (Rs.10,97,099.30) and diesel pump set (Rs.16,63,405.80).
The results of Life cycle cost analysis of SPV system without subsidy was found to be the least (Rs.5.24 lakhs) against diesel pump set (Rs.16.58 lakhs) and electric pump set (Rs.10.91 lakhs) Initially the cost of investment in SPV system was found to be higher but in the long run due to the absence of operating cost in the case of solar power, low maintenance and warranty provided by the companies for solar panels were found to be the reasons for lower Life Cycle Cost. Some of the companies provided 20 years of warranty for panels if installed without subsidy.

Situation 2: Solar Photovoltaic System with Government Subsidy

From the Table 3, it could be inferred that the total cost of solar pumps with a life span of 10 years (with subsidy) was found to be Rs.2,85,768.00 compared to diesel pump set (Rs.16,63,405.80), electric pump set (Rs.10,97,099.30). The life cycle cost of subsidized solar pump was only Rs.2.79 lakhs compared to Rs.10.91 lakhs in the case of electric pump and rs.16.68 lakhs in the case of diesel water pumps.
The Life cycle cost for SPV system with subsidy (0%) was found to be the least but were provided only 5 years of warranty for panels.

Conclusion

Comparative evaluation of the life cycle costs of the three alternate systems for water pumping indicated better economic feasibility of Solar Water Pumps compared to the Electricity and Diesel based water pumps. On the other hand, the ease of maintenance and longer life period of the solar water pumps are the major reasons for their promotion and adoption apart from being a source of renewable energy. The analysis also indicated that the solar water pumps are economically feasible even without the subsidy extended by the Government. The major issue in adoption of solar technology is higher initial capital investment compared to the other two options and this issue needs to be addressed by the Government through ease of credit with long term repayment options at a subsidized rate of interest.

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