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Research Article

FINANCIAL ANALYSIS OF SOLAR POWERED PUMPING SYSTEM FOR IRRIGATION IN TAMIL NADU

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Abstract: The study aimed to evaluate the financial feasibility of solar powered water pumping system for irrigation in Tamil Nadu. It covers 220 solar pump beneficiaries spread across five agro climatic zones. LCC was lower for solar pumping system (Rs.3.44 lakhs) than Electric pumps (6.77 lakhs) and diesel pumps (Rs.13.72 lakhs) and it was found to be the most efficient system than diesel and electric pump system due to its low maintenance cost and zero energy cost. By replacing the diesel pumps with solar pumping system, net present value was positive, benefit cost ratio was greater than one at 10% and 12% discount rate and IRR was found to be 14% which is more than the opportunity cost. With the subsidy component, the solar pumping system was found to be financially feasible. Based on the results of the study, it is suggested that bankers may be encouraged to promote innovative financial models to provide loan for solar pumping system to reduce the burden of the government in terms of subsidy.

Keywords: Solar Powered Pumps, Irrigation, Financial Analysis, Life Cycle Cost Analysis

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Introduction

Water pumping for irrigation is generally dependent on conventional electricity or diesel generated electricity. The energy from fossil fuels such as burning coal, oil and gas are widely used but these energy sources are depleting in nature, non-renewable and harmful to the environment as it spoils the surrounding atmosphere by releasing poisonous greenhouse gases like CO_2, CO, S, NO etc. These gases are not only harmful to human being as it creates heart problems and skin diseases but also increases global warming by emission of carbon compounds. Moreover, conventional energy production is quite uncertain as compared to present requirement and therefore, it is essential to harness renewable energy sources such as photovoltaic, wind and biomass for energy production. Among these photovoltaic is quite effective and there is enormous potential for off-grid photovoltaic deployment in India for various purposes such as rural lighting and electrification, for powering irrigation pump sets, captive power generation, urban applications and highway lighting [1]. Oparaku (2003) [2], Offiong (2004)v [3], Schmid and Hoffmann (2004) [4], Odeh *et al*. (2005) [5], Mahjoubi *et al*. (2010) [6], Sako *et al.* (2011) [7] evaluated the photovoltaic, diesel/ gasoline generator and grid utility options to supply power in different parts of the world in different crops and found that irrigation with solar energy are very much lucrative compared to diesel powered irrigation. Moreover, another study revealed that investment on solar pump is profitable and more risk free than diesel engine-operated pump [8]. Technical and economic analysis of solar photovoltaic water pumping system for irrigation of banana was analyzed using Life cycle cost (LCC) analysis. LCC of PV system was found to be Rs.35,117 /- while that of diesel engine (Rs.8,64,669/-). Net present worth (NPW) of the system after 20 years was Rs.209367/- and internal rate of return (IRR) was 29.64 percent. The benefit-cost ratio was 2.17 with a payback period of 3.35 years [9]. A study on economic feasibility analysis of solar tube wells in north-western Rajasthan revealed that with 75 percent and 68 percent subsidies on investment, solar tube wells generated impressive net present worth of Rs.1.10 lakh to Rs.2.60 lakh, benefit-cost ratio of 1.62 to 2.90, and internal rate of return of 10.95 percent to 40.33 percent.

However, without subsidies investment in solar tube well was not found economically feasible [10]. Socio economic viability of solar water pumps under Soan Valley Development Programme in Punjab revealed that subsidizing the solar water pumps makes more people to adopt the technology given that monthly bill of electricity or diesel are reduced to zero. NPV and LCC analysis revealed that there is a potential for substantial personal and environmental cost saving [11].

Tamil Nadu government installed off grid solar powered pumping systems from 2012-13 onwards to promote utilization of solar energy in agriculture sector and 4826 Solar powered pumping systems (AC pumps) have been installed at a total subsidy of Rs.185.77 Crores [12]. In this context, an attempt has been made to evaluate the financial feasibility of solar powered water pumping system for irrigation over diesel and electric pumps in Tamil Nadu.

Materials and Methods

In Tamil Nadu, the total number of solar powered pumping systems sanctioned during 2012-13 was 500 fixed type solar pumps and 1589 tracking type during 2013-14 and it was installed during 2016. All the five agro climatic zones in Tamil Nadu were selected excluding high rainfall and hilly zones. Purposive sampling was done for the selection of sample districts, taluks, and beneficiaries. In each zone, one district was selected based on the highest number of solar pumps installed. The same criteria were followed for the selection of taluks. Sixty fixed type and 160 track type beneficiaries were contacted for the study. Simple percentage analysis was done wherever possible to draw meaningful interpretation of the study. To have comparison, the sample farmers having diesel / electric operated pumps were also contacted for the study.

Financial feasibility analysis was worked out for the solar pumping system. The solar water pumping system installed in farmers' households by Agricultural Engineering department with 80% and 90% subsidy in Tamil Nadu. The following indicators were used to assess the feasibility of solar pumps.

Life Cycle Cost Analysis (LCCA)
Net present worth (NPW)
Benefit-cost ratio (BCR)
Internal rate of return (IRR)
Payback period (PBP).

Following assumptions were made to carried out the economic analysis of the system

The operating life of the PV panels was assumed to be 20 years and life of diesel engine / electric pumps assumed to be 10 years.
The interest rate on capital was assumed to be 12 percent
Maintenance cost of system assumed to be a 0.1 percent of total capital cost.
CO_2 emission per litre of diesel was taken as 2.7kg [13].
Availability of sunshine hours considered to be 300 days in a year.
Electricity cost was computed as Rs.2875 / annum for 5HP motor using electric motor.

Life Cycle Cost Analysis (LCCA)

This is a method for assessing the total cost of ownership of any assets in the life period. It takes into account all costs of acquiring, owning, and disposing of a system. In the present study, implementing LCCA for the current system (diesel driven pump / electric pump) and for the alternative that considered to replace it (PV pump system) gives the total cost of both - including all expenses incurred over the life period of the both systems. The purpose of LCC analysis is to compare different power options and to determine the most cost-effective system designs.
The life-cycle cost of both alternatives can be calculated using the formula:
LCC = [CC + MC + EC+ RC] - SC
where,
CC= Capital cost
MC= Maintenance cost
EC= Energy cost
RC=Replacement cost
SC=Salvage value.
i) Capital cost (CC) of a system includes the initial capital expense for equipment, the system design, engineering and installation. In this study, total capital cost has two components i.e. farmer's contribution (10 to 20%) and Government subsidy (90-80%).
ii) Energy cost (EC) of system is the sum of the annual fuel cost incurred for operating the system.
iii) Maintenance cost is considered as 0.1% of the capital cost for solar pump system, whereas the average cost incurred by the diesel pump / electric pump owners from the sample respondents were used for calculation.
iv) Replacement cost (RC) is the sum of all repair and equipment replacement cost anticipated over the life of the system.
v) Salvage value (SC) of a system is its net worth in the final year of the life-cycle period. A salvage value of 20 percent of original cost for mechanical equipment was used.
In the present study, LCC analysis was done for use of different energy sources for sugarcane cultivation.

Net present worth

The difference between the present value of all future returns and the present money required to make an investment is the net present worth for the investment. Discounting technique by which future benefits and cost streams can be converted to their present worth. The interest rate assumed (discount rate) was 12%.
Net present worth can be written as

$$NPW=\sum_{t=1}^{t=n}\frac{B^t-C^t}{(1+i)^t}$$

Where
Bt= Benefit in the year 't'
Ct= Cost in the year 't'
i= discount rate
t= time period (1,2, ...n)

Benefit cost ratio

Benefit cost ratio is the ratio between present value of the benefits to the present value of the cost. Benefit-cost ratio of more than one indicates that the project investment is feasible.
The benefit-cost ratio will be expressed as

$$Benefit\ cost\ ratio=\frac{\sum_{t=1}^{t=n} B_t}{\sum_{t=1}^{t=n} C_t}$$

Where
Bt= Benefit in the year 't'
Ct= Cost in the year 't'
i= Discount rate %
t= Time period (1,2, ...n)

Internal rate of return

The internal rate of return can be found out by systematic procedure of trial and error to find that discount rate which will make the net present worth of the incremental net benefit stream equal to zero.

$$\sum_{t=1}^{t=n}\frac{B_t\text{-}C_t}{(1+i)^t}=0$$

Payback period

It is the measure indicate the time required to recover investment costs. It will be estimated by adding net cash flow in the project until the cumulative net cash flow equal to initial investment

Results and Discussion

Profile of Sample Farmers

Profile of the sample farmers revealed that [Table-1], of the total sample, 83% were male beneficiaries and 17% were female. Average age of the solar pump beneficiaries was about 53 years. Illiteracy was found to be low in case of solar pump beneficiaries (nine percent). Education was found to be good i.e. nearly 77 percent of them had education beyond primary level and hence majority of them (91 percent) were educated. Average family size was around five per family i.e.4.65 members and the average farming experience was around 27 years. The sample farmers are medium sized farmers having more than 2 ha.

Solar Pumping System Installation

Majority of the sample farmers (59%) installed solar pumps for about five years and nearly 36% of them were installed for about 6 years and only five percent of them installed for about 4 years back which indicates that solar pumping systems is being operating in the field for about 4 -6 years in Tamil Nadu. Of the sample, 74% and 36 percent of the sample farmer's solar pumps were linked with Open well and bore well respectively, with 5 hp motor only. The average depth of open well was 50ft and the bore well was 426ft. The open well linked solar pumps have capacity of 30m whereas bore well linked solar pumps has a capacity of 50m which means they were able to withdraw / lift water upto the level from the ground.

Life Cycle Cost Analysis (LCC)

A comparison of the water-pumping system for irrigation viz., Solar pumps, diesel and electric pumps in terms of life cycle cost analysis was assumed for 20 years period and the details are shown in the [Table-2]. The average cost of the solar, diesel and electric pumps was found to be Rs.4.19 lakhs, Rs.28000 and Rs.3.17 lakhs, respectively. It is observed from the table that the LCC was lower for solar pumping system (Rs.3.44 lakhs) followed by electric pumps (6.77 lakhs) and diesel pumps (Rs.13.72 lakhs) for 20 years period.
The solar pumping system has higher initial cost than the diesel-powered pump and electric pumps but its recurrent cost proved declining over their current cost. However, aspects such as lower operation and maintenance costs, the more reliability as well as the longer expected useful life of PV systems could

Table-1 *Profile of Sample Farmers*

SN	Particulars	Solar Pumps (N=202)		Oil engine (N=19)		Electric Pumps (N=28)	
		Nos.	%	Nos.	%	Nos.	%
1.Gender							
	Male	168	83	19	100	27	96.43
	Female	34	17	-		1	3.57
2	Average Age	52.61		46.53		52.75	
3. Education							
	Illiterate	18	8.91	1	5.26	3	10.71
	Primary	28	13.86	1	5.26	4	14.29
	High school	59	29.21	7	36.85	9	32.14
	Hr. Secondary	37	18.32	6	31.58	7	25
	Graduate	60	29.72	4	21.05	5	17.86
4	Average Family size (Nos.)	4.65		4.32		4.35	
5	Farming experience (Yrs)	26.83		23.95		28.86	
6	Average Farm Size (ha)	2.79		2.51		2.34	

economically justify the higher initial cost of PV systems. The comparison of the life cycle costs of these three systems also noted that the operation and maintenance cost and fuel cost are higher for the diesel system, and if it is considered that fuel prices are increasing, these numbers could keep going up.

With respect to electric pumps, cost of obtaining new electric connection amounts to Rs.3.00 lakhs under Tatkal scheme and otherwise they have to wait for longer period (10 to 15 years). Hence, it is added in the capital cost along with the pump cost. Overall, it is concluded that solar pumping system was found to be the most efficient system than diesel and electric pump system due to its low maintenance cost and zero energy cost.

Table-2 *Life Cycle Cost Analysis (LCC)(in Rs./ for 5 HP for 20 years)*

Particulars	Solar pumps	Diesel pumps	Electric pumps
Capital Cost (CC)	419886	28000	317600
Maintenance Cost (MC)	8398	112000	58000
Replacement Cost (RC)	0	28000	17600
Energy Cost (EC)	0	1209300	287500
Total Cost	428284	1377300	680700
Salvage Value (SC)	83977	5600	3520
Life Cycle Cost (LCC)	344307	1371700	677180

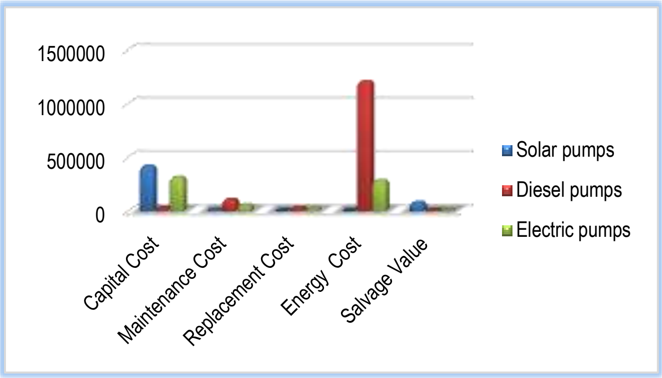

Fig-1 Life Cycle Cost Analysis for 20 Years

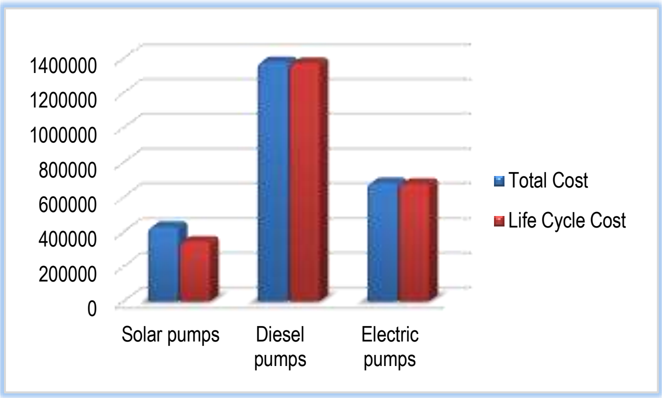

Fig-2 Total Cost and Life Cycle Cost over 20 Years

[Fig-1] shows that the fuel cost of the diesel system was really high compared with other costs within the system such as operation and maintenance cost, replacement as well as the capital cost. The total cost and life cycle cost for all the system throughout the 20 years' life cycle is shown in [Fig-2].

Financial Feasibility Analysis of Solar pumps over diesel pumps for irrigation

The solar system was assumed to be work for 300 days effectively at an average of 8 hrs per day. Maintenance cost and the benefit was worked out for irrigating one ha of sugarcane using solar pumps over diesel pumps and the details are furnished below. It is observed that the annual maintenance cost of the solar system was Rs.1007.39 and the expected annual benefit will be around Rs.64490 by way of reduction in use of diesel use (Rs.60465) and the reduction of carbon emission (Rs.5031.81). Hence, the net annual saving will be Rs.64490.

Operating days per year	300 Days
Operating hrs per day	8 Hrs/day
Operating hours per year	2400 Hrs/year
Area under irrigation	1.0 ha
Pump capacity	5 hp
Crop	Sugarcane
Investment Cost of Solar PV pumping system	
Total Capital Cost of Solar Pumps (A): Government Subsidy (80%) plus Farmers Contribution	419886
Farmers Contribution	100046
Cost of electricity production (B)	
Energy cost	0
Maintenance @ 0.1% of (A)	419.89
Rental Value of Land (Rs. /yr)	587.50
Cost (B) = Maintenance cost + Land Cost	1007.39
Profitability / Benefit (C)	
1.Cost of fuel (Diesel) saved (Rs. / year)	60465
2.Environmental benefit	
CO_2 emission = 889.20*2.68 (kg CO_2) kg /year	2383.06
a. Carbon tax benefit @ Rs.400 per ton	953.22
b. Carbon trading rate (24.16 $ per tonne)	4078.59
Total benefit (Fuel + Carbon emission)	65497.41
Net annual saving (D) =C-B (Rs./yr)	64490.02

The benefit and cost worked from the above table was used for analyzing the financial feasibility of solar system. Discounted analysis was used for analyzing the financial feasibility. The results revealed that with the total capital cost (government subsidy plus farmers Contribution) of solar system, the NPW was positive, BCR was greater than one at 10% and 12% opportunity cost and IRR was found to be 14% [Table-3] which is more than the opportunity cost. Hence it is concluded that with the subsidy component, the solar pumping system was found to be financially feasible. Payback period was worked out to 6.51 years.

Table-3 *Financial Feasibility Analysis of Solar pumps over diesel pumps*

Particulars	@ 10% discount rate	@ 12% discount rate
Net present worth (NPW)	Rs.129175	Rs.61837
Benefit- Cost ratio (BCR)	1.3	1.15
IRR	14%	
Pay Back Period (Years)	6.51	

Conclusion

The study results revealed that solar pumping system was found to be the most efficient system than diesel pumps due to its low maintenance cost, zero energy cost and also found to be financially feasible. Based on the results of the study, it is suggested that bankers may be encouraged to promote innovative financial models to provide loan for solar pumping system to reduce the burden of the government in terms of subsidy and with a view of creating green environment, solar pumping system may be promoted.

Application of research: Solar pumping system was found to be the most efficient system than diesel and electric pump system due to its low maintenance cost and zero energy cost and found to be financially feasible.

Abbreviations: LCC: Life Cycle Cost, NPW: Net Present Worth
BCR: Benefit Cost Ratio, IRR: Internal Rate of Return

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Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Tamil Nadu

Cultivar / Variety / Breed name: Sugarcane

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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