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RESEARCH ARTICLE

ASSESSMENT OF THE SUITABILITY OF SOLAR ELECTRICITY ADOPTION IN POULTRY INDUSTRY OF PAKISTAN

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ABSTRACT

This study was undertaken up to help farmers in the enhanced applications of solar energy at their poultry farms. As irregular supply of electricity and its high cost in the form of electricity bills and surcharge, is subjecting irreparable losses to poultry business. Solar energy with meager investment would help poultry business to flourish constantly by reducing one prime input factor. Each segment of poultry system whether it is heating, ventilation, humidity control or mechanized feeding, all require regular supply of power which could only be attained through solar energy that is available at the doorstep of the farmer for most part of the year. To tap this resource reliable and effective energy use system at poultry farms, especially of medium and small sizes. It seems easily manageable with the solar based energy. A comparison between both types for the benefit of our farmers an attempt is being made to come up with of poultry sheds i.e. conventional electricity and solar electricity based poultry shed is being made and payback period (26 – 27 years) and cost of one Solar based poultry shed (2.232 m^2) for 32 birds is obtained (Rs. 108500). Energy requirement for one laying hen is 4.85 kW-hr/year.

KEYWORDS

Poultry Farm, Solar Energy, Solar Poultry Shed

1. INTRODUCTION

Poultry industry in Pakistan contributes a large segment to the national economy with an investment of more than 70 billion of rupees and has become the second largest industry after textile in Pakistan. (SMEDA-Punjab, 2008). Current poultry production in Pakistan consisted of approximately 600 million layers, of which about 98 percent are maintained in cages. The meat component of the poultry industry primarily consists of chicken, followed by turkeys, although there is a relatively small number of waterfowl and game bird production mainly Bater. (Mazhar, 2009). SMEDA (Small and Medium Enterprises Development Authority) reported that poultry industry in Pakistan contributes heavily to the national economy with an investment of more than 70 billion rupees and has become the second largest industry after textile in Pakistan (SMEDA, 2008). SMEDA accounted that Pakistan is facing increasing energy shortfall crises and steeply increasing prices due to increased global oil prices combined with policy of denying subsidies under IMF and other international monitory agencies since 2007 has added enormous input expanse to poultry sector (SMEDA, 2002).

Hemes reported that baby chicks after hatching grew quite rapidly (Hemes, 1996). Broiler chicks reached 5 pounds in little more than 6 weeks thus need space to grow which usually was not limiting in most small-flock situations. Electricity plays a crucial role in poultry production. Production of poultry relies heavily on electricity for lighting, ventilation, heating and cooling, and running electric motors to periodically supply feed and water to the birds. Rising energy costs cuts into poultry producer's profitability throughout the country. In the past, large capital costs were deterring widespread investment in solar photovoltaic (PV) technology. However, the cost of PV panels has dropped from $25 per watt of late 1970s to less than $3.50 per watt in 2006, an 86% reduction and the downward trend continues until today (Bradford 2006).

Solar Energy systems are virtually maintenance free and will last for decades.
Once installed, there are no recurring costs. There is tremendous scope in Pakistan to utilize a huge number of clear sunny days per annum (290-310). The use of light and heat is a necessity to successfully raise poultry birds and this can be achieved with the solar energy in a more judicious way (http://www.wunderground.com/global/stations/41630.html). A group researchers reported that renewable sources of energy are very important for Pakistan as there is acute shortage of fossil fuels (Irshad et al., 1995). Among renewable sources, solar energy is of special significance being abundantly available. This study presented the solar radiation distribution, minimum in the North of Pakistan, increasing southwards to reach maximum in the center of Pakistan and then slightly towards the coastal region. The Quetta Valley received maximum solar radiation throughout the year. The nationwide average is 5.5 kWh/m^2/day with huge potential of solar energy.

This study was undertaken up to help farmers in the enhanced applications of solar energy at their poultry farms. As irregular supply of electricity and its high cost in the form of electricity bills and surcharge, is subjecting irreparable losses to poultry business. Solar energy with meager investment would help poultry business to flourish constantly by reducing one prime input factor. Each segment of poultry system whether it is heating, ventilation, humidity control or mechanized feeding, all require regular supply of power which could only be attained through solar energy that is available at the doorstep of the farmer for most part of the year. To tap this resource for the benefit of our farmers an attempt is being made to come up with reliable and effective energy use system at

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poultry farms, especially of medium and small sizes. It seems easily manageable with the solar based energy as 0.04 kWh use/day/house of 0.75 ft² area is needed per bird with a life cycle of 55 days (John et al., 2005). Economic feasibility of solar adoption for poultry producers is highlighted in this research. This manuscript analyzed PV under current cost setup and its potential to offer the farmers a variety of economic and environmental advantages over conventional electricity sources.

1.1 Objectives

The objectives of the study were:

- To establish the efficiency of solar electricity-based poultry farm comparing with conventional electrified poultry farm
- Assessment of conventional and solar electricity-based poultry farms
- To determine the temperature differential of both the types

2. Materials and Methods

This study was taken up to help / enhance farmers in the applications of solar energy at their poultry farms. An attempt is being made to come up with constant, reliable and efficient and economical energy system at poultry farms, especially of medium and small sizes, which it seemed, could be easily managed, with the solar based energy. Economic feasibility of solar adoption for poultry producers is highlighted in this research. This manuscript analyzes Photo Voltaic Cells (PVC) under current economic cost conditions, and its potential to offer the farmers a variety of economic and environmental advantages over conventional electricity sources (http://www.wunderground.com/global/stations/41630.html).

The research was focused on two aspects of the possible use of PVC applications for model poultry sheds at Sub-Campus T.T. Singh, University of Agriculture Faisalabad: technical feasibility and economic feasibility. Solar radiance data from Department of Farm Machinery and Power was examined and an analysis was conducted to determine optimal location and tilt angle of PVC panels. Faisalabad division has a very good overall solar-energy potential. The average daily exposure rate in this region amounted to approximately 5.5 kWh/m² as shown in Figure 1. The sun shined between 8 and 8.5 hours daily, or approximately 3,000 hours per annum (GTZ Report, 2005).

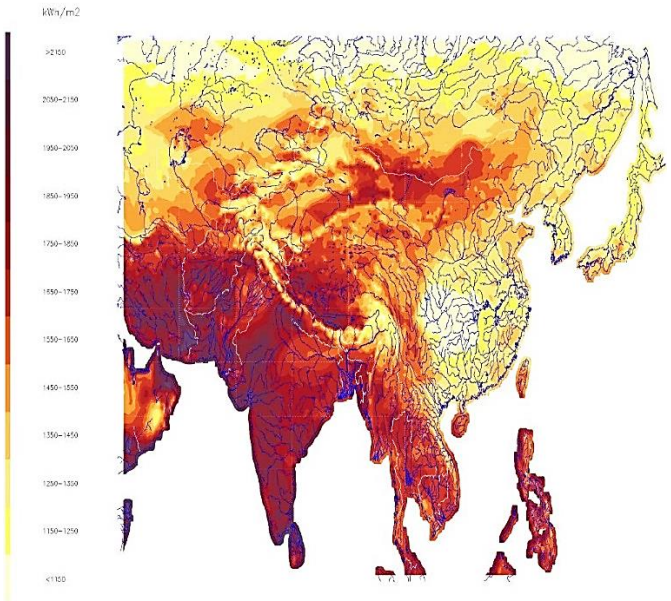

Figure 1: Global radiation, annual mean 1981 to 2000.

2.1 Overall Research Design

This study assessed the potential for PVC applications to the poultry industry by modeling a typical poultry farm operation using data from the model poultry sheds situated at the UAF Sub-campus, T.T.Singh. Analysis included an assessment of the economic potential of PVC for this application. This research was focused on two aspects of the possible use of PVC applications for poultry sheds i.e. technical and economic feasibility. The technical analysis included temperature of the poultry sheds to be dealt with to assess the efficacy of the shed structure. The economic analysis included reviewing electricity usage and costs from several farms, assessing the effects of PVC on electricity costs, reviewing existing incentives and calculating the effects of net metering. Solar radiance data from T.T Singh was examined and an analyzed to determine optimal location and tilt angle of PVC panels. T.T Singh receives an average of 5.5 kWh/m²/day of global solar radiation (GTZ Report, 2005). The statistical analysis was also performed. Comparison of Means was done by applying Z-test.

2.2 Procurement of Material

The poultry operation consisted of five (1.83m x 1.22m x 1.83m) conventional poultry houses available at Sub-campus T.T. Singh UAF and each cage housed 32 birds with a grand total of 160 chickens at average bird density is 0.067 m²/bird. Average growing season is assumed to be 55 days, with an average kWh use/day/house of 0.04. If five (5) growing seasons are completed annually, electricity consumption per house is estimated at 11 kWh. Thus, gross electricity requirement for five poultry houses will be 55 kWh. The study was conducted on poultry house of same dimensions for PV system at same time and the two types of electrical application were compared (Hemes, 1996).

The following materials were procured in order to conduct laboratory test on the electrical appliances using PVC system.

- Solar Panel Board (PVC and frame with bracket)
- Battery
- Inverter
- Control & Switch
- Bulbs
- Electric Wires
- Electric Heater
- Thermometer
- Humidity Meter
- Insulating Materials (Polythene Sheet)
- Construction Material for five 1.83m x 1.22m x 1.83m poultry shed.

While for the construction of six poultry sheds, consisting of five conventional electricity based and one solar electricity-based poultry shed, following materials were also procured.

- Bricks
- Cement
- Sand
- Plastic Sheets
- T-iron
- Mesquites
- Mesh wire

2.3 Parameters

Temperature variation was main parameter set for analysis purposes.

The assessment was made incorporating:

- Sizing of the PV System.
- Cost of PV systems.
- Period of Analysis

2.4 Development of Poultry Sheds

The study was done with the aim of comparison & determination of economic and technical feasibility of solar electricity-based poultry farm with the poultry farms running on the conventional electricity. For this purpose, five poultry sheds (1.83m x 1.22m x 1.83m) were constructed to run on conventional electricity whereas one poultry shed of same dimension as of shed no. 3 was made with same material to produce chicks using electricity obtained from solar radiation.

2.5 Construction of Conventional Electricity based Sheds

In this regard, total five numbers of poultry sheds; 1.83 meter long, 1.22 meter wide and 1.83 meter high, were constructed (Figure 2). For ventilation purpose an adequate space left in the walls in which mesh wire was installed for the safety of chick.

Table 1: Material Costs for Construction of A 1.83m X 1.22m Conventional Electricity-Based Poultry Shed	
Material	**Prices (PKR)**
Bricks	2000
PVC Pipe	780
Gravel 8 Feet	215
Sand 23 Feet	290
Cement 2 bag	730
Rent	100
Bag	180
Tape	45
Steel Bars	200
Wooden Bars	300
Polythene sheet	80
Steel bar for roof	210
Masson fee	1800
Mesh wire	1600
Wooden frame	150
10 kg Cement + Sand + Gravel	200
Total	**8880**

Figure 2: Compared conventional electricty based poultry shed

2.6 Construction of Solar Electricity Based Shed

In this respect, poultry shed of same dimensions as conventional electricity-based poultry sheds, i.e 1.83 meter long, 1.22 meter wide and 1.83 meter high, was constructed (Figure 3). The construction expenditures detail solar electricity-based poultry shed is given in Table 2.

Table 2: Material Costs for Construction of A 1.83m X 1.22m Solar Electricity-Based Poultry Shed	
Material	**Prices (PKR)**
Bricks	2000
PVC Pipe	780
Gravel 8 Feet	215
Sand 23 Feet	290
Cement 2 bag	730
Rent	100
Bag	180
Tape	45
Steel Bars	200
Wooden Bars	300
Polythene sheet	100
Steel bar for roof	210
Masson fee	1800
Mesh wire	1600
Wooden frame	150
Iron frame for PV Panel	1300
300-Watt PV Panel	90000
300-Watt Inverter	3500
Battery (OSAKA-70A)	5000
Total	**108500**

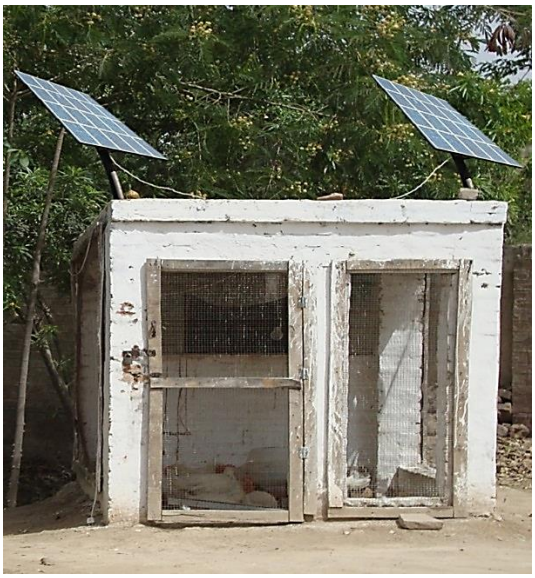

Figure 3: Solar electricity based poultry shed.

2.7 Selection of Materials

2.7.1 PV Panel Selection

According to electricity needs two PV panel of 150 Watt each were attached in series to get a total 300-Watt PV system capacity with 85% efficiency and installed on this shed. The detailed specifications of the panels are given in Table 3:

Table 3: Detailed Specification of PV Panel of 150 Watt	
Maximum Power	150 W
Peak Output	9.72 A @ 17.2 V
Approximate watt-hours per day*	1050
Approximate amp-hours per day*	68.04
Length	158 cm
Width	79.3 cm
Depth	5.0 cm
Weight	13.5 kg

*Based on 7 hours of average daily peak sunlight hours.

2.7.2 Battery Selection

A battery of 12 Volts and 70 AH (OSAKA N70) was also attached with the PV panel for the storage of electricity.

2.7.3 Inverter Selection

An inverter of 300 Watt was used to convert 12V DC electric supply to 240V AC.

2.7.4 Poultry Birds Selection

Layer hens were selected for the experiment. Average laying period of laying hens was 50-54 weeks (Wilson et al., 1997).

2.7.5 Temperature Management

A 100 watt electric heater was used to maintain the temperature.

2.7.6 Light Management

An 8 watt energy saver was used to fulfill the light requirements of the birds.

2.8 Data Collection

2.8.1 Electricity Consumption

Data, including daily kWh demand for heating, cooling and lighting were recorded from poultry sheds at UAF Sub-campus, T.T. Singh. Annual electricity consumption was estimated in kWh.

2.8.2 Temperature Data

A thermometer was installed in each poultry shed and temperature readings were taken after every 6 hr in a day. In summer months when long sunny days, readings were taken at 12:00 am, 6:00 am, 12:00 pm and

6:00 pm whereas in winter when there were lesser day timings, readings were taken at 11:00 pm, 5:00 am, 11:00 am and 5:00 pm. Temperature was maintained whole the year according to layer hen requirements.

2.8.3 Sun Shine Data

Daily sun shine time and solar radiance timing were recorded for the year. Average sunshine time during summer was 12-13 hrs while in winter was 10-11 hrs. No. of sunny days was 305 during the period of analysis.

2.8.4 Sizing of the PV System

The kW size of an appropriate PV system was determined experimentally. For the electricity needs of the poultry sheds, a system of 300W appeared optimal.

2.8.5 Costs of PV system

Estimates of PV system installed prices vary among manufacturers, type of PV system, and differences in installation costs. A range of installed PV costs were used covering low and high values. The analyzed range is Rs. 300/Watt.

2.9 Analysis

2.9.1 Period of Analysis

The system was analyzed over a period of 12 months from May 2009 to April 2010.

2.9.2 Cost Analysis

After gathering all the data cost analysis was performed. Life period of the solar system was assumed to be 30 years. Percent increase in electricity prices was analyzed. Payback period was calculated, and feasibility of the research was determined.

2.9.3 Statistical Analysis

As the individuals were same and n > 30 so statistical analysis was performed using Z-test by comparing the Means at 0.05 level of significance (α).

3. Results and Discussion

This study was conducted to investigate the feasibility of solar electricity adoption based on efficiency, reliability and economy of solar electricity in poultry industry. By great blessing of the nature (Approximately 290-310 sunny days in a year in Pakistan), efforts were done to develop a solar electricity-based poultry sheds. Assessment was done by comparing it with conventional electricity-based poultry shed. Temperature data was recorded daily at 6 hours interval throughout the year. Heating, cooling and lighting requirements (kW-hr/day) for layer were determined. On the basis of daily kW-hr usage, monthly cost of electricity was calculated, and energy consumption analysis performed. Cost of conventional electricity was observed in last five years and yearly increment in electricity rate was determined. A comparison between both types of poultry sheds i.e. conventional electricity and solar electricity based poultry shed was made and payback period was also determined. (http://www.wunderground.com/global/stations/41630.html). The results obtained are discussed as follows.

3.1 Energy Analysis

Temperature data of T.T. Singh was obtained by taking reading at 6 hour interval on daily basis. Heating and/or cooling time required for each poultry shed to maintained the required temperature was recorded. In the hot months, temperature was maintained as required by layer hens by cooling with the help of two 25 watt fans. Total electricity consumed by the fans was noted and daily usage of kW-hr was calculated by multiplying the wattage of fan with time of use. Whereas in winter, temperature was maintained by heating according to the requirement of layers. A 100 watt electric heater was used for heating. Time for burning the heater was recorded in hours and then kW-hr for each day was calculated by multiplying it with capacity of heater in kilowatt (0.1 kW). Lighting is another important factor in layers. An 8 watt energy saver was used for lighting. 24 hour lighting For the first two days was followed by 23 hours of lighting for next two weeks. In week 2 to 10, normal sunlight was enough and after 10th week it was also reduced to eight hour per day by applying curtains. After 20th week, fifteen (15) hours constant light was given till the end of the year. Daily kW-hr usage was calculated and analyzed.

3.2 Cost Analysis

On the basis of monthly electricity consumption, cost per poultry shed was calculated. Presently electricity tarrif for commercial connections is approximately Rs. 12/kW-hr. Since, electricity unit (kW/hr) rate incresed by 15% during last year, so, an annual 15 % increment in electricity prices was taken for next 30 years. The graph shown in Figure 4 shows electricty usage cost comparison between conventional & solar electricity based poultry shed. In the 6th yearthere is equal electricity usage cost (Rs. 3616.67) for both conventional & solar electricty based sheds whereas cost from solar energy only riases slightly afeter every seventh year (Replacement of battery after 7 years with 15% increased rate) while increasing continously till the end of 30 years, keeping rest of the factors constant such as maintenance, product price variation, secure human resources, etc. Table 4 represents monthly kW-hr usage of poultry shed. We can conclude that maximum kW-hr were consumed in month of June when it is hot weather and minimum in March when weather is neither hot nor cold. Total 155.27 kW-hr used in 12 months to raise 32 layer hens with laying period of 52-54 weeks.

Table 4: Electricity usage in 12 months in kW-hr

Month	kW-hr Used			
	Heating	Cooling	Lighting	Total
May 2009	2.64	9.01	1.25	12.90
June 2009	0.00	17.02	0.00	17.02
July 2009	0.00	15.97	0.00	15.97
August 2009	0.00	14.55	0.00	14.55
September 2009	0.30	11.47	0.17	11.94
October 2009	1.40	7.32	0.99	9.71
November 2009	6.05	2.57	0.96	9.58
December 2009	11.81	0.21	1.24	13.26
January 2010	17.67	0.02	1.24	18.93
February 2010	7.71	0.71	0.90	9.32
March 2010	1.85	6.07	0.74	8.66
April 2010	0.06	12.89	0.48	13.43
Total kW-hr used in year	**49.49**	**97.81**	**7.97**	**155.27**

It is clear from the Table 5 that usage cost for conventional electricity-based poultry farm is just Rs. 1866 in the year (2010) which is very cheap than usage cost of solar electricity-based poultry farm (Rs. 3616.67). Usage cost for conventional electricity-based poultry farm increase 15% annually and after 6 years, both usage costs become equal as shown in Table 5. After then, usage cost for conventional electricity-based poultry farm continuously increases and after 30 years (In 2039), it will become Rs. 107435.80 whereas usage cost of solar electricity-based poultry shed only increases up to Rs. 7660.20 as shown in Table 5. It is also clear that electricity cost for one layer hen with conventional electricity is Rs. 58.31 now and it is projected to be Rs. 3357.37 after 30 years. But in case of solar electricity, it is Rs. 113.02 now (2010) and is projected to be Rs. 239.38 after 30 years, as shown in Table 5.

3.3 Payback Period

It can be deducted from Table 5 that in the 6th year, cost of both type of electricity becomes same (Rs. 3616.67) and after that solar electricity is practically free. Difference between both types of yearly electricity costs was taken as shown in column (7) of Table 4.14. Column (8) shows the addition of cost difference (From column 7) of consecutive years up to 30th year i.e. 2039. It can be observed that in 26th year initial cost of solar electricity-based poultry shed is recovered. So, the payback period was determined to be 26 years.

3.4 Statistical Analysis

Since the individuals were same and sample size (n = 30) was large, hence the statistical analysis was done by comparison of Means using Z-test. Standard deviation and means of conventional and solar electricity costs were calculated. By applying Z-test, Z_{cal} was determined by using Equation 01 and compared with Z_{tab}. Tested the hypothesis at α = 0.05, level of significance.

H_o: $\mu_E = \mu_S$

H_1: $\mu_E > \mu_S$

Test statistics used are as under:

$$Z_{cal} = \frac{\bar{X} - \bar{\mu}}{\sqrt{\frac{S^2}{n}}} \quad (1)$$

Since the computed value of Z_{cal} (4.055) > Z_{tab} (1.645), therefore H_o was rejected and H_1 is accepted showing that usage cost of solar electricity is less than the usage cost of conventional electricity over 30 years period.

Table 5: Electricity cost, profit/loss and payback period estimation for conventional and solar electricity-based poultry sheds.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sr. No	Year	With Conventional Electricity		With Solar Electricity		Profit / Loss	Payback Period Analysis
		Cost for 32 Layer Hens / year	Cost for 1 Layer Hen / year	Cost for 32 Layer Hens / year	Cost for 1 Layer Hen / year		
		(Rupees)	(Rupees)	(Rupees)	(Rupees)	(Rupees)	(Rupees)
1	2010	1866.00	58.31	3616.67	113.02	-1750.67	-1750.67
2	2011	2145.90	67.06	3616.67	113.02	-1470.77	-3221.44
3	2012	2467.79	77.12	3616.67	113.02	-1148.88	-2619.65
4	2013	2837.95	88.69	3616.67	113.02	-778.72	-1927.60
5	2014	3263.65	101.99	3616.67	113.02	-353.02	-1131.74
6	2015	3753.19	117.29	3616.67	113.02	136.52	-216.50
7	2016	4316.17	134.88	3616.67	113.02	699.50	836.02
8	2017	4963.60	155.11	4438.10	138.69	525.50	1225.00
9	2018	5708.14	178.38	4438.10	138.69	1270.04	1795.54
10	2019	6564.36	205.14	4438.10	138.69	2126.26	3396.30
11	2020	7549.01	235.91	4438.10	138.69	3110.91	5237.17
12	2021	8681.36	271.29	4438.10	138.69	4243.26	7354.17
13	2022	9983.57	311.99	4438.10	138.69	5545.47	9788.73
14	2023	11481.10	358.78	4438.10	138.69	7043.00	12588.47
15	2024	13203.27	412.60	5382.74	168.21	7820.53	14863.53
16	2025	15183.76	474.49	5382.74	168.21	9801.02	17621.55
17	2026	17461.32	545.67	5382.74	168.21	12078.58	21879.60
18	2027	20080.52	627.52	5382.74	168.21	14697.78	26776.36
19	2028	23092.60	721.64	5382.74	168.21	17709.86	32407.64
20	2029	26556.49	829.89	5382.74	168.21	21173.75	38883.61
21	2039	30539.96	954.37	5382.74	168.21	25157.22	46330.97
22	2031	35120.95	1097.53	6469.10	202.16	28651.85	53809.07
23	2032	40389.10	1262.16	6469.10	202.16	33920.00	62571.85
24	2033	46447.46	1451.48	6469.10	202.16	39978.36	73898.36
25	2034	53414.58	1669.21	6469.10	202.16	46945.48	86923.84
26	2035	61426.77	1919.59	6469.10	202.16	54957.67	101903.15
27	2036	70640.78	2207.52	6469.10	202.16	64171.68	119129.35
28	2037	81236.90	2538.65	6469.10	202.16	74767.80	138939.48
29	2038	93422.43	2919.45	7660.20	239.38	85762.23	160530.03
30	2039	107435.80	3357.37	7660.20	239.38	99775.60	185537.83
Total		**811234.44**	**25351.08**	**154666.67**	**4833.33**	**656567.81**	

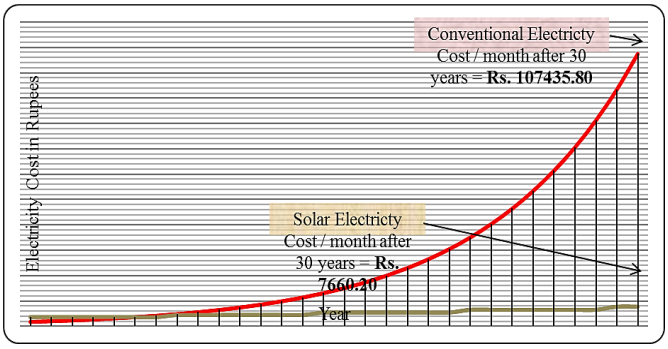

Figure 4: Comparision of electricty usage cost between conventional and solar electricty based poultry shed on yearly basis.

4. Conclusion

Initial cost of Solar Electricity is high described per shed of described dimensions, (Rs. 108500) as compared to Conventional Electricity based poultry shed (Rs. 8800). In Solar Electricity based poultry shed, after 6 years electricity will be free of cost. Energy requirements per laying hen are 4.85 kW-hr/year. After 26th year, initial investment is recovered. The life of battery used in Solar Electricity based poultry shed is 7 years. In December, January and February, electric heater is used for heating to maintain the temperature for laying hens at 20-22°C. While in May, June and July, electric fan is used for cooling to maintain the temperature for laying hens at 20-22°C. The There is no power interruption in Solar electricity-based poultry shed. There is no maintenance and running cost except replacement of battery (after every 7 years) and the lighting requirement is constant throughout the year.

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