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FEASIBILITY AND COMPARATIVE ANALYSIS OF SOLAR POWER TUBE WELL WITH EXISTING CONVENTIONAL SYSTEMS AND ITS UTILIZATION IN IRRIGATION OF THE AGRICULTURAL LANDS.

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ABSTRACT

Solar energy plays an essential role in creation of the electricity in all the fields of life. Now a day with the increased demand and high prices of the electricity production, it is not feasible to run all the electrical equipment on the electricity being supplied by the local authorities. In this research paper a comprehensive study based on the feasibility of the solar energy for the tube well has been conducted in district Bhakkar, Punjab. The tube well discharge was $25mm^3$/sec having a total hydraulic head of 25m. The borehole depth under the earth is 110 ft (50 ft blind + 60 ft screen) using borehole diameter of 12.7cm (5 in). A three-stage submersible pump of 15.24cm (6 in) diameter was laid in borehole to a depth of 65 ft. The submersible pump get power from 24 solar panels of having a magnitude of 360 watts each. In wintry weather the discharge of solar operated powered tube well varies from 5.00 to 24.00 mm^3/sec and in summer it ranged from 12.00 to 25.00 mm^3/sec. The peak discharge of the solar tube well properly changed into as 5 to 6 hrs/day in winter and summer time, respectively. The sugar cane crop was planted and irrigated with water pumped from a tube well that was operated by consuming solar energy and the production capacity of the tubewell is about 95 tons/hectare in a year. The cost volume profit analysis of a properly powered solar tube well vs a diesel-operated tube well nicely confirmed that the capital recovery period of solar powered tube well would be 1.42 years of its 10 years of usable life with a 36% internal rate of return (IRR). At discount rates of 2, 4, 6, and 8%, the solar powered tube well's BCR (Benefit Cost Ratio) was 1.5, 1.42, 1.38, 1.62 respectively. At discount factor of 2, 4, 6, and 8%, the solar-powered tube well's NPV (Net Present Value) was 0.91, 0.87, 0.84, 0.75 million rupees, respectively. The Results indicated that the solar tube well is a sensible desire and need of the modern time due to its quick payback length.

1-INTRODUCTION

Pakistan's population is predicted to reach a total of 320 million by 2050, expanding at a pace of 1.92 percent, posing difficulties in addressing the nation's rapidly increasing needs for food, energy, and water[1]. Agriculture is the largest employer in the world and is essential to maintaining food security worldwide[2]. The Pakistani borderline is located among latitudes 23350 and 37050 N and 60500 and 77500 E, occupying an area of 796,096 km^2. The region belt experiences 185 to 290 bright days per year, a high level of sun shine (95% coverage), and sufficient sunshine hours (7 to 7.5 h per day)[3]. Depending on where you live, the horizontal surface of the boundary receives an average global irradiance of 200 to 250 W/d, producing 1500 to 3000 hours of sunshine annually[4]. There is 2.8 MW of solar energy capacity easily available in Pakistan in terms of solar energy.[5].There is a risk of groundwater overexploitation if solar tube wells or pumps are used in Pakistan because there is an absence of a well-defined national strategy regarding the application of solar technology for pumping groundwater. Around 73% of Pakistan's land is thought to be openly or indirectly irrigated utilizing ground water drawing out of 60 billion m^3 placing it as the third-largest consumer of groundwater for irrigated agriculture on a global scale[6]. Approximately 16% of the 1.2 million tube wells, according to an estimate, are powered by electricity, with the remainder using diesel as a fuel[7]. Pakistan experienced fast tube well growth as a result of groundwater consumption for agriculture approaching 50% due to a lack of canal water sources[8]. By 2013, the nation's total count of groundwater extraction points had climbed to over one million, using a sizable portion of the energy used in the agriculture sector[9]. Pakistan's energy needs are increasing at a pace of 8–10% annually[10]. According to one estimate, the agriculture sector has used 11% of the total energy distributed in the nation, primarily for the operation of tube wells, which requires the exploitation of energy resources, including renewable energy[11]. A deep tube well in Pakistan costs three times more to pump 1000 m3 of water than a shallow tube well[12]. As illustrated in Figs 1 and 2, the precise data revealed that Pakistan has a Photo voltaic power potential of 1200 to 2100 kWh/kWp per year, which is derived from the annual total of worldwide horizontal irradiation (1300 to 2300 kWh/m2). Pakistan's southern and southwestern regions receive more sunlight than its northern regions received, and hence the country's solar potential specially in Baluchistan and Sindh area has the world’s second highest values in Solar potential[13]

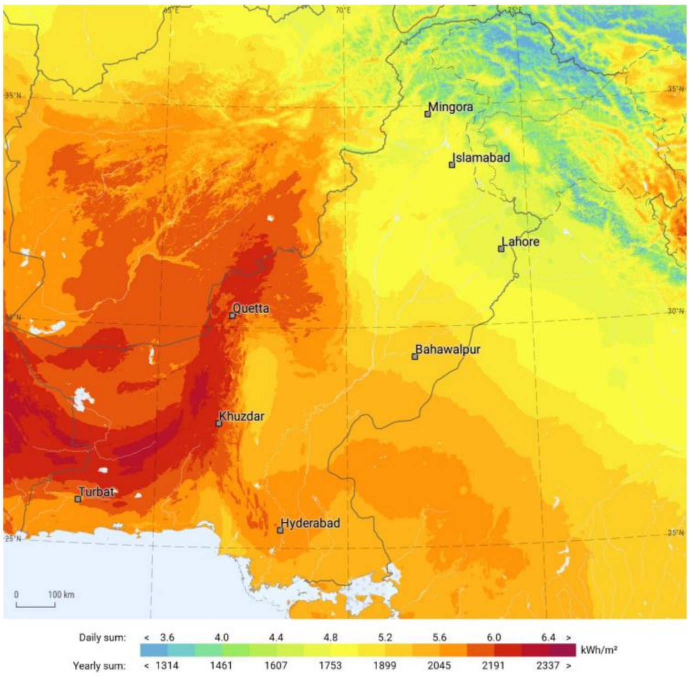

Fig 1: Sum of global horizontal irradiation (Kwh/m^2) [13]

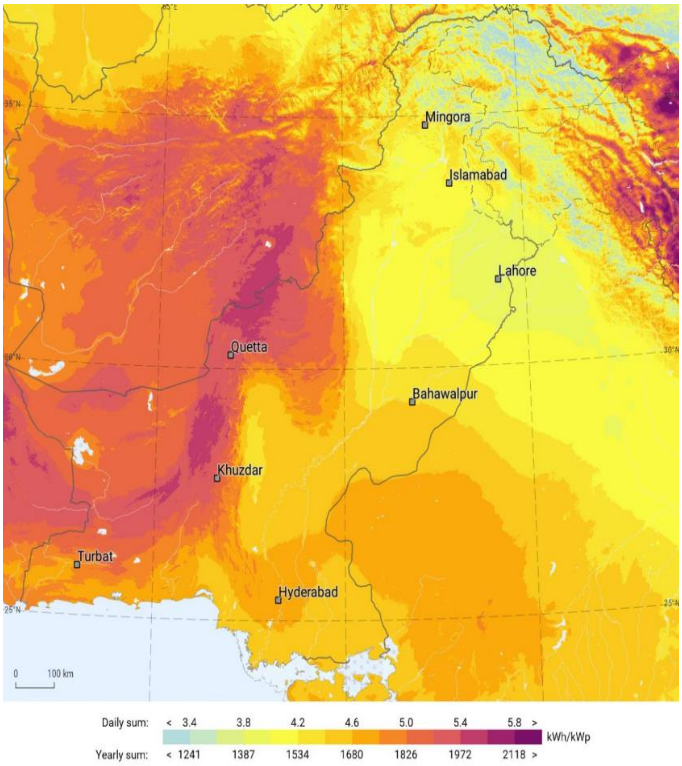

Fig 2: Photovoltaic Power Potential of Pakistan [13]

According to a study, Pakistan's southern and western regions, whose sun radiation levels are the numerous highest in the whole world, have exceptionally high solar energy potential. According to the report, these areas have the capacity to produce more than 20,000 GW power of electricity from radiations received from the solar energy[14]. Solar energy is an effective and dependable alternative energy source. Thankfully, in keeping with National Renewable Energy Laboratories (NREL), United State of America, day by day that the solar radiations in Pakistan variety from 4.7 to 6.2 KWh/kWp because of area and natural endowments. Submersible pumps and solar energy could be used in a combination to aid with irrigation needs. Tube wells powered by solar energy can be used without concern about fuel supplies or power cables. Without worrying about the fuel prices , fuel supply and electrical hookups solar powered tube wells can be operated under normal day light conditions [15].

This research has been studied to take a look at the financial viability of a sun-powered tube well in Punjab, Pakistan, considering the dearth of strength, the excessive cost of fuel, and the importance of irrigation within the agricultural region.

2-MATERIAL AND METHODS

Specifications of the Research Project:

In this research paper one year operating readings were executed on solar powered tube well installed at the southerner Punjab place in the city of Bhakkar to identify its economic feasibility. The illustration of the solar panel is shown in **Fig 3**.

Fig 3: *Solar Panel plates for solar tube well.*

The solar plates were moved by a portable stand to open and close the panel in the specific times or at the time of operation as it will help to operate in a more efficient way and it could also be used to save the space to operate in the fields, the diagram of the portable stand is shown in the **Fig 4**.

(A) Operating Condition Stand

(B) Moveable

Fig 4: A & B, Portable stands for solar panels.

The discharge of the tube well was 25mm^3/Sec having a dynamic head of 25 m. The bore had a casing diameter of 12.7 cm (5 inches) and was drilled to a depth of 110 ft (50 ft blind + 60 ft screen). **Table 1** shows all the technical specification about the solar tube well.

Table 1: Technical Specification

Sr.	Technical Specification	Value	Unit
1	Depth of Bore	110	ft
2	Check Valve	4	ft
3	Suction Pipe	6	in
4	Delivery Pipe	5	in
5	Suction diameter of Pump	6	in
6	Delivery diameter of Pump	5	in
7	Discharge of Pump	25	mm^3/Sec
8	Water Level	80	ft

Tube well Discharge:

After every hour, the volumetric approach was used to measure the tube well's discharge from solar power. Equation 1 was used to calculate the discharge after measuring the volume of water for a predetermined amount of time. The tube well's maximum discharge times throughout the summer and the winter were also calculated. The Discharge of water is shown in **Fig 5**.

$$Q = \frac{V}{t} \text{ -------------- (1)}$$

Where: **Q** = Discharge, **V** = Volume of water collected, **t** = time of the water collected

Fig 5: Discharge of water

Crop area and Time frame:

The 2.5 acres (1.0 hectare) crop of sugarcane was planted at Bhakkar, Punjab, and were irrigated by using water pumped system which was operated by a solar powered tube well. For one year, sugarcane crop was planted in the month of October and harvested the following November as shown in **Table 2**.

Table 2: Time Frame of the Project.

Sr No	Category	Duration	Check In	Check out
1	Winter timing Overall	08 Hours 30 Minutes	08:00AM	04:30PM
2	Winter timing Peak Hours	06 Hours	09:00AM	03:00PM
3	Summer Timing Overall	09 Hours 30 Minutes	07:30AM	05:30PM
4	Summer Timing Peak Hours	09 Hours	08:00AM	05:00PM
5	Area of Land Irrigated per day	2.5 Acres, 1.0 hectare		
6	Total Area Irrigated by the System	7.5 Acres, 3.0 hectare		
7	Type of Crop	Sugarcane		

3-BREAKEVEN ANALYSIS

Benefit cost ratio (BCR):

The **Equation 2** was used to determine the BCR, which is a ratio of the present value of benefits to the present value of costs.

$$BCR = \frac{\sum \frac{B_t}{(1+r)^t}}{\sum \frac{C_t}{(1+r)^t}} \text{------------- (2)}$$

Where: $\mathbf{B}_t$= Benefit in each year, **Ct**= Cost in each year, **r** = Discounted rate, **t** = Number of years

Net present value (NPV):

NPV is the value which shows the project's net worth, is the difference between the present value of benefits and the present value of expenses as shown in **Equation 3**. It is an example of a discounted cash flow approach and dynamic investment appraisal.

$$\text{NPV} = \sum \frac{B_t}{(1+r)^t} - \sum \frac{B_t}{(1+r)^t} \text{--------------- (3)}$$

Internal rate of return (IRR):

Due to the fact that it is independent of the use of an arbitrary discount factor, the IRR is regarded as the most suitable instrument for assessing the economic effectiveness of irrigation systems[16]**.**At a specific rate of discount, the previous two measurements are calculated. In this instance, the implicit rate of discount is calculated so that present value of benefits and expenses should be equal and NPV equal to Zero. Now the interest rate of "**r***" at which zero NPV is achieved in the Internal rate of return, so **Equation 4** was utilized to determine IRR.

$$\text{Internal Rate of Return} = r^* \text{ Such that NPV} = 0 \text{ --------------- (4)}$$

4- RESULTS AND DISCUSSION

Solar powered tube well Discharge:

The actual discharge quantity of the operating solar powered tubell in the normal day light condition was measured from Sun rise to sunset and it is shown in **Fig 6** to displays the discharge average value of the solar Powered tubewell. Only the peak hours of tube well discharge for the summer season (May-October) and winter season (November-April) months were taken into consideration for the analysis and readings. The average solar-powered tube well peak hours were discovered to be 6 hrs in winters and 8 hrs. in summers.

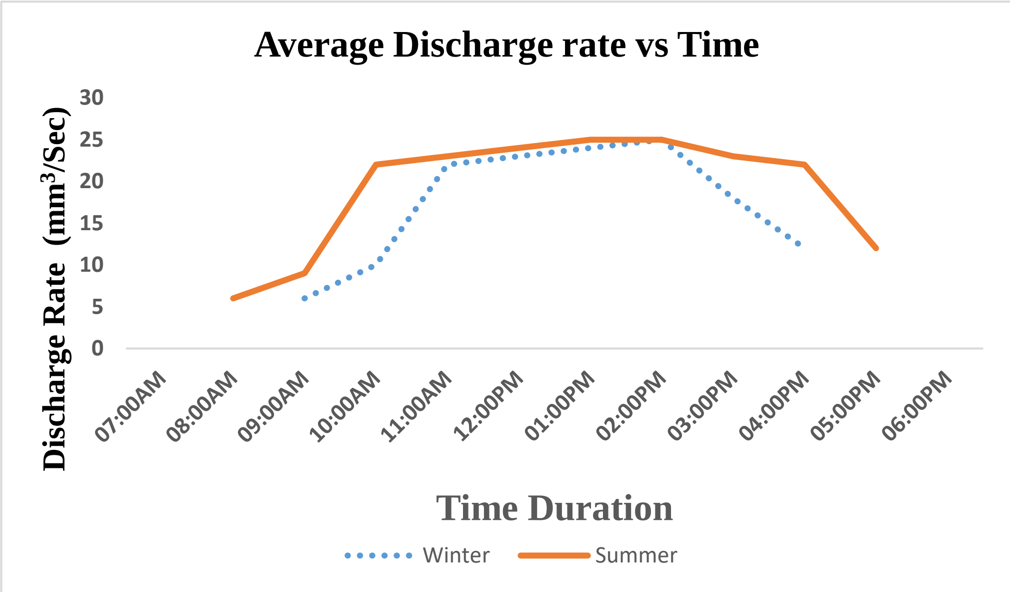

Fig 6: Discharge vs Time duration Graph.

Crop Yield

According to crop yield results, 95 tons/ hectare of sugarcane was produced annually.

Capital and Operational Cost analysis of Solar Vs Diesel tube wells.

The capital cost of solar powered tube well is Rs. 1,364,040 (1 US dollar = 295.0 Pakistan Rupees) having the discharge of 25 mm^3/sec and at the other end the capital cost of diesel operated tube well (25mm^3/sec) is Rs. 3,00000. In order to pump the same amount of water by utilizing the solar system tube well, the operational cost of a diesel operated tube well was determined to be Rs. 320835. The fact of capital and operational price for both solar powered and diesel operated tube wells as well as WAPDA operated tube wells are illustrated in the **Table 5**.

Table 5: Comparison of Solar, Diesel and WAPDA Capital and Operational Cost.

A Cost comparison (Capital Operational) of the Solar, Diesel and WAPDA Operated Tube well.			
Name of the Item	**Solar Operated**	**Diesel Operated**	**WAPDA Operated**
Capital cost			
Motor1 + Pump cost	35,000 + 27,000	1,40,000	35,000 + 27,000
Solar Panel 360W Each (8.640kWh) @ PKR 61 per	527,040	Nil	Nil

Watt			
Frame and fitting cost	600,000	25,000	350,000
Labor	50,000	50,000	50,000
Controller	35,000	Nil	Nil
Bore + screen + filter	50,000	50,000	50,000
Wiring cost1 / Belt cost2	15,000	10,000	15,000
Miscellaneous	25,000	25,000	25,000
Total Amount	**13,64,040-/**	**3,00,000-/**	**5,52,000-/**
Operational cost			
Solar Powered Tube well Operational Cost/Day	Nil	7x293 = Rs.2051/Day	11.19 W x Rs.15 x 6 hrs = Rs. 1000
Operational cost of one year (Rs.)	Nil	2051x365 = **7,48615**	1000x365= **365000**
Number of Years required to meet the cost of solar Tube Well	Nil	1364040-300000=1064000 1064000/748615 **1.42 Years**	1364040-5,52000=812040 812040/365000 **2.22 Years**

The **Table 3,4** shows a comprehensive analysis of the project (Electric and Mechanical) and all the items are mentioned with the market price.

Table 3: Electric Equipment Cost Detail.

Detail of Cost of Electric Motor		
Name of Item	**Specifications**	**Amount PKR**
Electric Motor	15 hp	95,000
VFD	15 hp	60,000
Wapda Charges (Approval + Transformer 25 KVA + 2 Poles+ Electric Wire + Meter etc.) Complete in all respects.	25 kVA Transformer, 600ft distance from main line, 2 poles	3,50,000
Running Cost @ 1kwh	-	Nil
Per hour cost	15x11.19x6	

Table 4: Mechanical Equipment cost detail.

Detail of Cost of Diesel Engine			
Name of Item	**Specifications**		**Amount**
Diesel Engine	12 hp	-	140,000
Fuel Consumption	12 hp	0.5 liter/hr	Nil
Mobil oil after every 100 hours	12 hp (4 liter)	0.04 liter/hr	
	7 liter in 6 hrs	7x293= Rs.2051/Day	

Fig 7 shows a detailed analysis of the feasibility between solar panel, diesel and WAPDA operated Tube well in term of cost and a clear indication to achieve the breakeven.

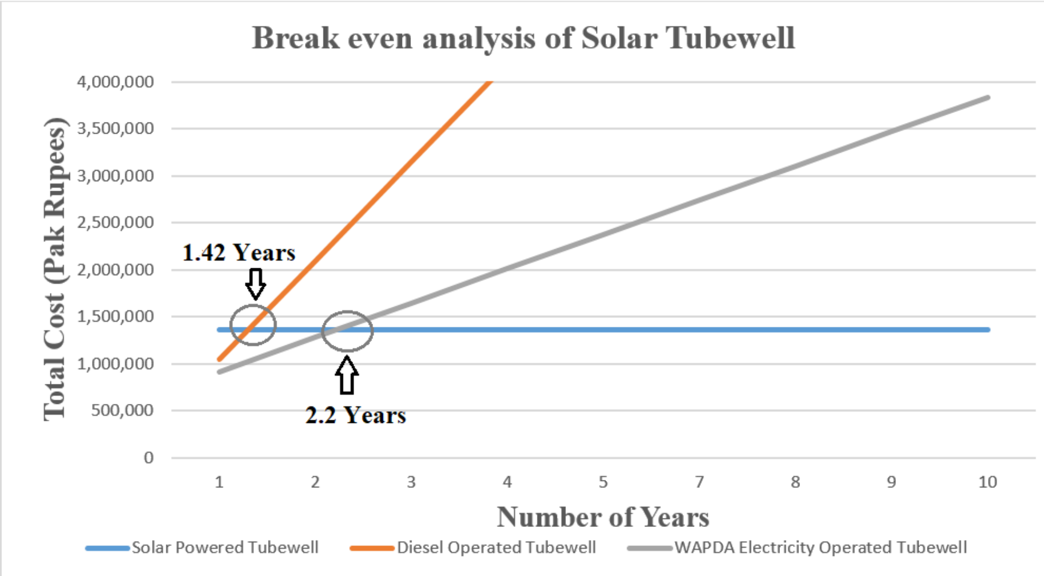

Fig 7: Break even analysis of Solar tube well

Discounted capital budgeting analysis

The analysis in the **Table 6** shows that the IRR of the solar powered tube well is 36%. The (BCR) of solar tube well at different values 2% 4% 6% 8% is 1.50, 1.42, 1.38, 1.62 respectively and Net present value (NPV) in millions at 2% 4% 6% 8% is 0.91, 0.87, 0.84, 0.75 respectively.

Table 6: Discounted capital budgeting analysis

(BCR)				**(NPV) (Million)**				**(IRR)**
2%	**4%**	**6%**	**8%**	**2%**	**4%**	**6%**	**8%**	**Nil**
1.50	1.42	1.38	1.26	0.91	0.87	0.84	0.75	**36%**

5-CONCLUSION

It is concluded by the results that solar powered tube well provides us very feasible and economical results and pay back all the investment in a period of 1.42 years as compared to diesel engine and 2.2 years as compared to WAPDA Electricity. The Solar tube well will continue its production till the next 10 years with a very low maintenance cost. Furthermore, the solar tube well is environmental friendly with no emission of hazardous gases and zero noise pollution. It is the reason that now solar tube well has become attractive and affordable equipment in the field of agriculture and irrigation system. It's far more environmentally useful and suitable for usage by farmers in the future to keep the sustainability of the world and agricultural environment.

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