SOLAR TECHNOLOGY AND GWADAR PORT CITY OF PAKISTAN: SOCIO-ECONOMIC EVALUATION

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ABSTRACT: *Energy technology system depends on certain social and economic dynamics defined as social acceptance and comparative cost effectiveness of the technology in relevant economy and environment. Solar power favorable climate, lower-lower middle class facing electricity shortfall in Gwadar-Balochistan-Pakistan; set a perfect starting point for the introduction of solar technology that can relieve the electricity power choke. The Potential for "Solar Technology Utilization" hereon referred to as STU, in Gawadar is 70%; this scale of frequency distribution bases on; market competitiveness, user comfort, and cost effectiveness. This study augments the existing literature on STU as a solution to the energy predicament in Pakistan and specifically details the benefits of STU in Gawadar (port city across the South-Western coast of Baluchistan) with data analysis and personal observation. The paper provides sufficient evidence regarding STU as an intelligent option to develop the local population's living standards.*

Key words: Solar Technology Utilization (STU), Socio-economic evaluation, Potential tendency, Comparative cost effectiveness

1. INTRODUCTION

Sustainable energy is the growth sector of the future, depletion of resources, along with the world precariously balanced at the precipice of global climate change, is making it impossible for fossil fuels to be feasible in the long run [2] From Fossil fuels to sustainable energy is a daunting trek, where the former caters to 88% of the world's primary energy necessities, sustainable sources are still untapped and require high maintenance.The banes of Non-renewable energy resourcesbecame clearer in the wake of the "Copenhagen Accord" and the "Kyoto Protocol"; renewable energy is the way forward as a matter of survival for the human race. "Cleaner energy choices" are more viable and incorporation renewable energy can alter the environmental situation [11].International Renewable Energy Agency (IRENA) has regarded developing countries as more fertile ground for renewable energy [23]. Moreover the world is well aware to the dangers of carbon emissions and the environmental hazards of burning fossil fuels, the depletion is merely one side of the coin; the other offers a bleak picture of energy security[13].

Table 1: Pugh Matrix [14]

Critical System's Requirements	Priory Index	Petrol Generator	Diesel Generator	Hybrid Solar and UPS	Solar System	UPS	LPG Generator	Natural Gas Generator
Capital Cost	5.58	0	1	-5	-3	0	-1	-1
Space allocation cost	5.44	0	0	-4	-4	3	0	0
Running Cost	3.72	0	0	-1	-1	1	0	0
Installation Cost	4.06	0	0	4	5	2	2	3
Maintainability	3.64	0	0	-3	-2	0	0	0
Reliability	3.69	0	0	3	5	1	-1	-2
Total Life	5.67	0	1	3	5	-4	-1	-1
Exhaust Factor	2.61	0	0	5	5	5	1	1
Noise Factor	2.31	0	-2	5	5	5	0	-1
Vibration Factor	3.47	0	0	5	5	5	0	0
Safe to handle	6.63	0	-1	1	2	0	0	0
Continuity of Power Supply	4.24	0	0	5	-2	-3	-1	0
		0	0	52.28	62.41	42	-9.13	-7.17

It is clear from the Pugh Matrix provided in Table 1, that as far as alternative energy sources are considered, solar energy possesses the best performance score and is ideal for the consumer as well. The performance score of solar power is 62.41, beating nearly all traditional power options [25]. According to the World Energy Outlook sponsored by BP and lieu of 2014 consumption estimates, the global reserves of crude oil face depletion within four decades, while a clock of six decades has been placed on natural gas reserves [26]. Renewable energy resources factor for 11% of the world's energy demands and are projected to reach almost 60% [4].

1.1 Suitability of Solar Technology for Pakistan-Balochistan

Pakistan falls in a sunlight rich semi-arid zone. The topography of the barren province of Balochistan can be converted into a boon if groundwork for solar technology is laid. Pakistan has 300 days of sunlight in a year; giving it one of the highest global insolation averages. The region receives 3000 h of sunlight per year giving it a potential electrical capacity of 1900-2200 KW [1].Pakistan's "Mean Global Irradiation", is found to be 3hours and 1.9-2.3 MW h/m2 per year. At such a high average global insolation, (Almost 19 to 20 MJ/m2 per day), with a yearly average sunshine period of 8 to 8.5 h and these numbers are among the highest across the globe, making the region the perfect candidate for solar technology utilization.A regular global irradiation up to 23 MJ/m2, is a easily available throughout 80% of consecutive days in this region [5] These are promising parameters; making the area ideal for Photo Voltaic and other solar power options [4]Baluchistan is mostly dessert and dry land with an abundance of sunshine and a severe deficiency of infrastructure and transport capability. The sporadic nature of the population settlements in Baluchistan makes a network of power grids and transmission lines unlikely and easily compromised. Each settlement needs to have its own singular setup, with individual training and maintenance. The traditional grid lines that pose a substantial power loss and the linkage between sparsely populated and distanced settlements are impractical and offers no intelligent solutions. Under the CPEC umbrella, the Gawadar Port alone has seen an investment influx of 0.66 billion dollars assuring that the vicinity will be a thriving port city. The last two decades marked tangible1progress in the usage of "Photo voltaic cells" in Pakistan. National Institute of Silicon Technology (NIST) under the "Ministry of Science and Technology" is a pioneer in the confident utilization of solar cells, modules, and systems as PV technology caters to lower energy demand it is nonetheless a solid step forward [18]

1.2 Solar Technology Utilization Prospects

STU prospects can be specified across three clear dynamic:

a) Inefficient electricity supply
b) Comparative cost benefits of solar technology utilization
c) Long-term lower costs and benefits of STU economically, socially and environmentally.

Energy production is lagging to the mammoth rise in demand, in the last two decades it has tripled and yet only half the households have electricity. In Pakistan the Per capita electricity supply is 443kW h versus the massive 12,500 kW h in USA or the 7500 kW h in Japan [7]. Currently the energy composition in Pakistan; Thermal power 68%, Hydroelectricity 30 % and, the Nuclear power 2%. Despite the recent options of Hydraulic fracturing and an abundance of natural resources concentrated in Baluchistan Pakistan has a lavish oil budget for power generation of Rs. 80 billion per year [9]. Solar energy technology would lessen the rate of urban migration which hampers the ability of cities to address their environmental problems. Moreover, Utilization of solar technology will reduce the dependency of rural areas on firewood significantly.The average household requirement of the Gwadarregion is 100W at best, can be catered by a household STU setup. The generators utilization depends on expensive transportation of fuel.The Pakistani government took an initiative in 2006 under the label of ''policy for development of renewable energy for power generation: Employing small Hydro, Wind and Solar technologies'' [20].The initiative had the following provisions of: Power projects that are Independent, Captive cum grid power project, Sequestered grid power projects.Under this initiative the Pakistani government inaugurated its first successful solar powered venture in 2012 in the capital, Islamabad.STU is low maintenance and can be easily taught as well [15]. The public health department of Baluchistan has installed solar water pumps. However, as mentioned due to a low population density (77 % of the Baluchistan's population is rural concentrated. 90% of the area is yet to be electrified). Only diesel/petrol generators are utilized as alternate source of energy [20].

Sustainability advocates autonomy. Solar Energy Research Centre (SERC) Pakistan's high temperatures have made it imperative to install STU. 70 % of the country's population lives in 50,000 villages, greatly distanced from the National grid [22]. Linking these villages to the national grid is costly. However, a solar panel can provide energy and each home autonomy and empowerment [8].In most rural regions of Pakistan wood and animal waste is still primarily used for burning. The Alternative Energy Development Board (AEDB) has started a solar housing scheme in which 1000 solar homes were made operational for the purpose of STU. The AEDB has taken up the task of providing alternative cooking methods by supplying villages with solar cookers and this in turn has reduced localized deforestation by a mammoth 80%. This progressive step has aided economic progress and created some level of autonomy in these villages. The STU model presents a superior solution to energy security concerns. STU has the potential to reach most of Pakistan's population. STU is an urgent solution to an accumulative issue [9]. Pakistan's total power generation capability is 23, 538 MW. This is poor to say the least as power usage has gradually increased by nearly 80% in a period of last 15 years. If the Pakistan Water and Development Authority's (WAPDA) report is considered power demands by 2020 will have reached 40,000.[17]This paper draws a legitimate comparison between non-renewable (here petrol generators) and renewable (Here solar energy) for the providence of domestic electrical supply. Solar energy has a higher initial cost (also reduced since the advent of the technology) while the free sun replenishes solar power system.

The PV setup can possess greater value in Pakistan due to temperatures touching 50 Celsius. Solar Photovoltaic (SPV) can; Increase efficiency of an entire setup, Reduce

transmission and distribution losses, Produce readily consumable energy that can sufficiently provide for a single unit. [4]

The paper now purposes the potential of STU in Gwadar with clear objectives,

a) To establish STU through the lens of the socio-economic viewpoint of consumers and service providers in Gawadar.
b) Gwadar's STU potential as proven and supported by primary research and data by presenting comparative cost analysis.

To draw a feasibility regarding the incorporation of STU in society potential tendencies for solar technology utilization is estimated through following variables:

- Average income of the population,
- Preexisting alternative energy technology, response and feasibility
- Consumer friendliness
- Electricity billing

Comparative cost analysis comprehends the Installation costs, Maintenance costs and Operational cost.

The essential queries of the research are as follows:

a) What is existing consumer practice with respect to alternate modes of electricity technology in Gwadar?
b) How to identify a feasible space for the utilization of solar technology?

2. Methodology

The guiding principle of the conducted research was that the approval rate and tendency towards STU technology does not solely rely upon individual consumers or the parameters of a given technology. A key driver of acceptance is "individual socio-economic behavior".

2.1 Research Designfor socio-economic evaluation of STU in Gwadar

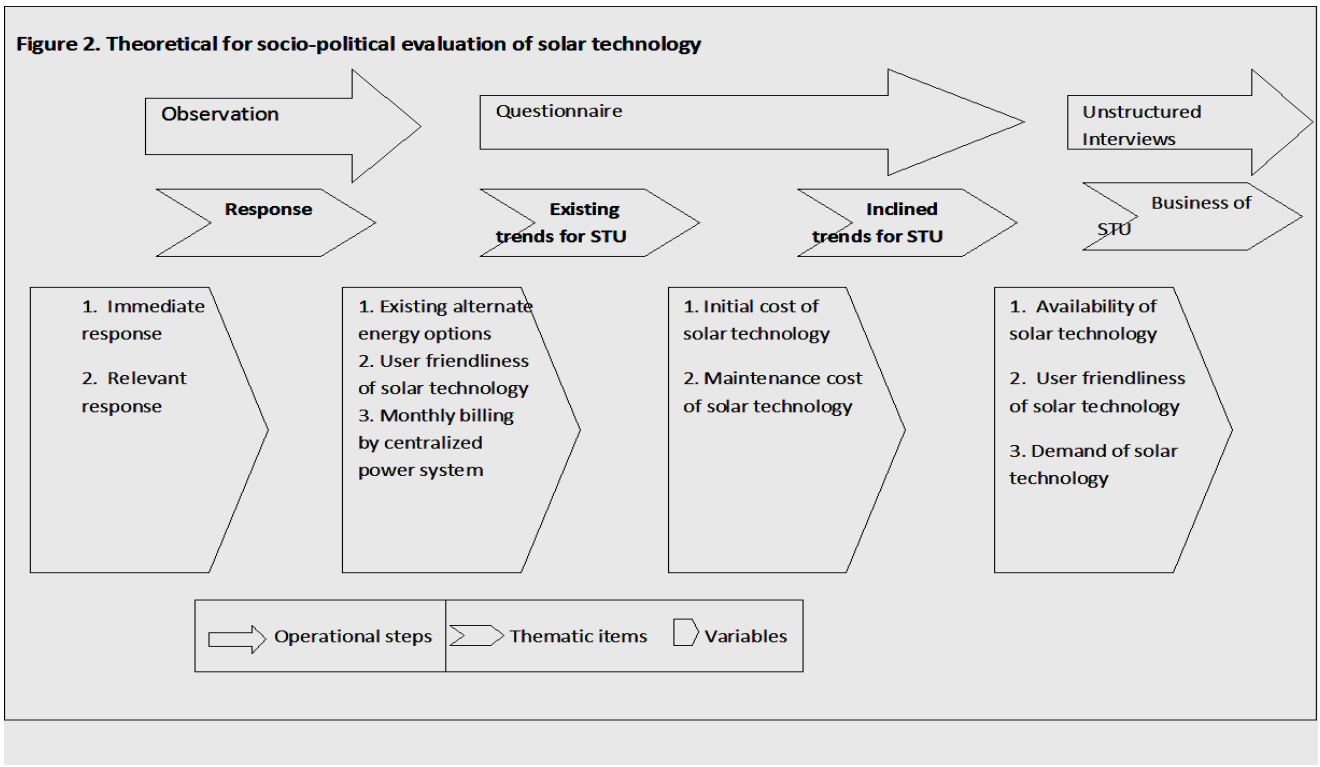

Figure 1 Design for socio-economic evaluation of solar technology utilization.
Source: [14]

Alternative power technologies are accessible. The study gauges solar technology in competition to alternative power sources and in this study it is petrol generators. Solar technology was regarded as the "change variable". Welfare factor or betterment of living circumstances was regarded as the "outcome variable". The evaluation process factored socio-economic principles and was regarded as the "linking variable" The study's theoretical structure quantifies and calculates the potential and feasibility of STU (see, Fig. 2). The study gauges solar technology in competition to generators (run by petrol or diesel).A privileged group was specified, their responses and primary observations were the foundation of this paper. The research was carried out between December 2016 and February 2017 and comprised of the following:

2.1.1 Questionnaires

The questionnaire was intended specifically to highlight and understand the socio-economic feasibility of STU within Gwadar. The accumulative data gathered via the questionnaires is primary in nature and is not accessible via any census or secondary form of data, publically available. The aim of such data is to establish precision and concise information. All questions flowed from the general to the specific and are worded in simple language. Purposive sampling was applied to carefully select a group of 120 subjects. The structure of the questionnaire followed two specific outlines; Potential tendencies for solar technology

utilization, Cost based tendencies for solar technology utilization.

2.1.2 Unstructured interviews

Unstructured interviews were conducted and designed to attain a clear understanding regarding prevalent market trends for STU and availability in the nearest commercial city, Karachi. The relationship with the prevalent power generation options was also considered in these interviews, by focusing service providers, generator shops. Data collection was consolidated and further cemented through observations.

2.1.3 Data analysis

Purposive sampling was utilized for collection of data and analyzing. Mode (frequency distribution and standard deviation were used while data values were computed by SPSS (24)

3. Findings and Analysis

The acceptance of fresh technology and moreover the adherence to it relies on existing trends and value provided by the technology in a socio-economic context. The findings of this study show that this context can be analyzed by a two-prong approach

3.1 Potential tendencies for solar technology utilization

The study measured the variables:average income of the population, prevalent alternative energy technology response & feasibility and electricity billing to present the potential for STU.

Table 2 Average Monthly Income of the Respondents

Monthly Income of the respondents	N	Minimum	Maximum	Mean	Std. Deviation
	120	10,000	70,0000	36,667	18,211.33

Income Level	Frequency	Percentage
Rs. 10,000	18	15%
Rs. 30,000	62	52%
Rs. 50,000	22	18%
Rs. 70,000	18	15%
Total	120	100.0

The data varies from the lower to the lower middle class with income of respondents between Rs. 10,000/- per month and a maximum income ofRs. 70,000/-. Standard deviation of the data is 18,211.33 (see Table 2).Respondents were selected based on alternate energy utilization (fuel powered generators) in their homes or as aspirants of STU.The income is used as a denominator of sustainable energy development with social consequences. Data gathered is free from discrimination of any nature.

The study subjects all utilized fuel powered generators for electricity. Nearly all respondents were either average educated or illiterate citizens. The data laid the presumption that parameters of technology operation are not reliant on the formal education. Gawadar is a semi-desert zone with minimal rainfall and annual average temperature of 26.2 Celsius with an upper limit of 48 Celsius and 106 mm of annual precipitation. Centralized grids have a daily power cut time of 4-8 hours. At times the respondents have faced a complete power trip lasting the whole day. Nearly 50% of the local population is reliant on generator as an alternate power source. The local population is ignorant to the benefits of STU, mostly relying on Karachi (ten hour drive) for business. Chinese investors under the CPEC umbrella have made use of solar power in Gwadar for the first time during the construction of Gwadar port in 2002-2006. China announced plans to deliver 200 sets of solar power panels to the local populace. The adjoining areas along with schools and hospitals stand to gain STU

.

Table 3: User friendliness of generator technology

Response	Frequency	Percentage
Yes	26	22.66
No	47	39.16
To some extent	47	39.16
Total	120	100.00

Majority of the respondents labeled the alternate power source (generators) difficult and costly. Results are exhibited in Table 3. (39.16%) of the respondents were unhappy with generators while (39.16%) of the respondents were also dissatisfied at some extent. These results indicate potential for an STU trend.

Table 4: Average monthly billing charged by WAPDA

Choices	Frequency	Percentage
1500 to 3000	75	62.5
More than 3000	45	37.5
Total	120	100.0

Table 4 clarifies 62.5% of the respondents receive an average monthly billing between Rs.1500/- to Rs.3000/-. Many consumers are paying higher prices which indicate that the economic potential of STU has a clear spot. The alleviation to the respondents' dilemma is in STU.

3.2 Comparative cost effectiveness

Comparative cost evaluation indicates that while the installation expense of solar technology is high in comparison to alternative Technologies, it has low maintenance, and operational costs are

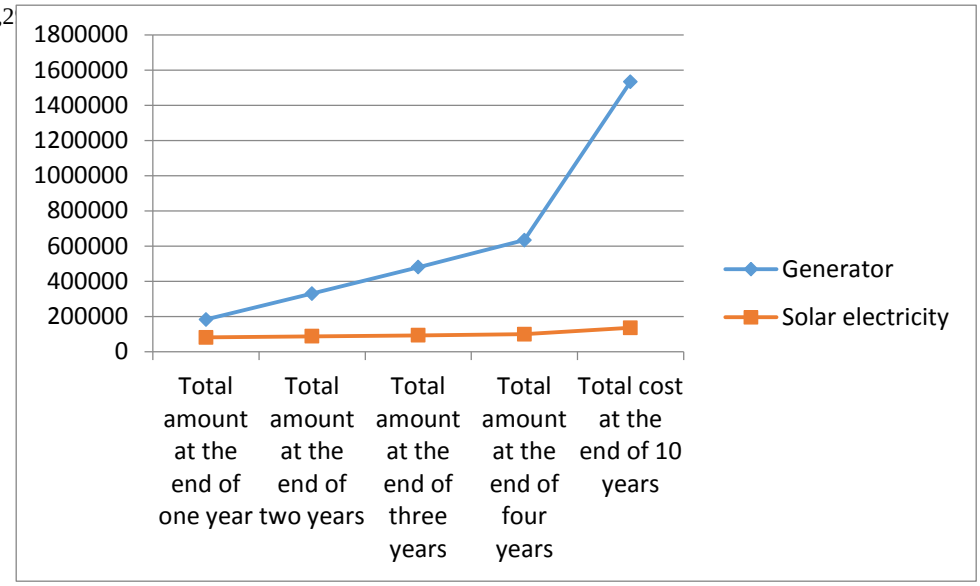

Figure 3: Comparative Cost Analysis

Table 8: Comparative Cost of STU

Cost factors	Generator	Solar electricity
Initial cost	30,000/-	75,000/-
Maintenance cost per annum	3000	15000/-
Operational cost(per Annum)	150,000/-	-15000/-(monthly average bill=1250)
Total amount at the end of one year	183,000/-	81,000/-
Total amount at the end of two years	330,000/-	87,000/-
Total amount at the end of three years	480,000/-	93,000/-
Total amount at the end of four years	633,000/-	99,000/-
Total cost at the end of 10 years	153,30000/-	135,000/-

minimal also further proof can be seen in reference [19] 65% of the respondents are found inclined for STU (see Table 5).

Table 5: Inclination for solar technology utilization

Responses	Frequency	Percentage
Yes	84	70
No	33	27.5
To some extent	3	2.5
Total	120	100.0

Data collection indicates that affordability is not the major factor contributing in decision making, also see reference [21], affordability is second if utility and urgency is primary. The socio-economic driving force is the major variable, pushing the graph in favor of the STU trend perception. Introduction of the technology can completely turn the wave in favor of STU also see reference [16], if introduced properly. 66.66% of the respondents chose Rs. 75000 option (see Table 6).

Table 6: Initial cost of solar technology utilization

S No.	Options	Frequency	Percentage
1	Rs. 75000/-	80	66.66
2	Rs. 150000/-	40	33.33
3	Rs. 250000/-	Nil	00
	Total	120	100.0

* The cost is in PKR

Yearly price trajectory shows that the market is ripe for more engagement with solar power, prices have lowered significantly. Market survey of Karachi service providers shows affordability and the low cost trend for STU. The data collected through unstructured interviews and observation show a clear affordability of solar panels as a long-term investment. Table 7 shows the 80% of respondents chose for option of 10,000 as maintenance cost of STU.

Table 7: Maintenance solar technology utilization

Choices	Frequency	Percentage
Rs. 10,000/-	96	80
Rs. 20,000/-	21	17.5
Rs. 30,000/-	3	2.5
Total	120	100.0

* The cost is on annual basis in PKR

Maintenance and operational cost of diesel/petrol generators isexpensive whereas the capacity for STU maintenance is found modest and sustainable over ten years (see Table 8).

The study established STU desirability, potential around four income brackets (see Table 1). 52% respondent households (living as joint household) having Rs. 30,000 income showed interest towards STU as a 'JOINT VENTURE'. This adds another affordability dynamic to the utility of solar power. The increasing importance of Gwadar and the international economic clout around the port makes it an excellent starting ground for STU.

This study was earlier conducted in socio-economic prospects of STU for households within the demographic location of district Abbottabad, Pakistan [22] the results were 65% in favor of STU. Once this study was extended to Gwadar the produced 70% findings indicate the likeliness and acceptance for STU.

4. CONCLUSION AND RECOMMENDATIONS

Data collection indicates that affordability is not the major factor contributing in decision making. The socio-economic driving force is the major variable, pushing the graph in favor of the STU trend perception. Introduction of the technology wouldimprove the quality of life if STU introduced properly. The respondents informed that most of the time they spend Rs. 5000-7000 as operational cost of generators that costs them mental, physical and financial fatigue simultaneously.

Under the headline of *'Potential tendencies for solar technology utilization'* measurement of average income, consumer level of satisfaction with the prevalent use of alternate energy source of generators, and the monthly billing to central grid identified the households discomfort with the available energy systems. Under the headline of *'Comparative cost effectiveness'* while presenting the initial, maintenance and operational costs the study found the respondents willing to opt STU highest 70%.

According to a report published by IRENA (International Renewable Energy Agency); policy makers, especially from developing countries should actively pursue "value creation" [10] Local conditions and the various stages of renewable energy deployment are a perfect fit for a Solar Power Project in Gawadar. Every segment of a solar energy project value is achievable. This value seeps from the initial planning to the sub processes [23]. Balochistan is ripe ground and has a higher potential for value creation in all three aspects; operations, maintenance and delivery.Research clearly shows positive factors that are providing a picture of the situation in Gawadarthat how STU can be a true changer for the socio economic situation of the region.

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Annexure 1

Solar Technology and Gwadar Port City of Pakistan: Socio-economic Evaluation

Questionnaire

Name: (Optional)_____

Age: _____

Qualification/ Occupation: _____/_____

Income (monthly) _____

Section A

Potential tendencies for solar technology utilization

Tell us to assess the potential of solar energy utilization in Gwadar

Prompts

- What alternate type of electricity resources you use during load shedding?

  (a). UPS (b). Generators

- Are you satisfied with alternate sources of electricity you are currently using at your home?

  (a). Yes (b). No (c). To some extent

- How much is the monthly operational cost of generator for you?

(a) 5000 (b) 7000 (c) 9000

- What is monthly average electricity billing of your home?

  (a). 1500 to 3000 (b). More than 3000

Section B

Comparative cost effectiveness

Tell us to identify the problems in solar electricity utilization in Gwadar in socio-economicperspective.

- Can you afford to invest in solar electricity?

  (a). Yes (b). No

- As solar electricity overcomes drawbacks of generators as it is pollution free and it is reliable because it gets electricity from sun, will you like to opt solar electricity?

  (a). Yes (b). No

- Do you know the level of availability of solar electricity appliances in the market?

  (a). Yes (b). No

  - How much you can spend initially to utilize solar electricity?

  (a) Rs. 75,000 (b). Rs. 1,50, 000 (c).Rs. 2,50,000

  - How much you can spend to maintain sustainable solar electricity solution?

  (a). 10,000/- (b) 20,000/- (c). 30,000/