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Design of Solar PV System for Educational Institutes in Rural Areas of Khyber Pukhtunkhwa, Pakistan

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Abstract
Pakistan is the country facing deficiency of electrical power. The metropolitan areas of the country, however, have the moderate electric energy supply while rural areas suffer from the problem of no supply of electric energy as one of the serious problems in these areas. In this paper, the Solar PV System parameters are calculated for educational institutes as the solution of this no or insufficient electric energy supply in rural areas of Kpk. The main aim of this research is to increase the social and computer literacy level in these areas keeping in mind the cost effectiveness of the Solar PV system. Computer literacy rate improvement requires the uninterrupted power supply in rural areas which can be done by the installation of Solar PV System in these areas. The average load of one High, one Middle and one Primary school is forecasted for computer labs is made on daily, weekly, monthly and annual basis. The current WAPDA supply system for these areas is examined which is insufficient for the operation of computer labs in educational institutions. According to the WAPDA tariff rules, the electricity consumption for operating computer labs in these schools have been calculated if there is uninterrupted electric power supply. At the end the cost effectiveness of the WAPDA power supply system and that of the proposed Solar PV System is analyzed. At the end it has been concluded that Solar PV System is the best option for eliminating the electric energy supply problem for improving the social living standards and computer literacy in these areas.

1. Introduction and Problem Statement

Pakistan is an energy hungry country and has been facing crucial electrical energy crisis for the last few decades. The total installed capacity of the county is about 23,000MW, while the total generation over the year ranges from 12000MW to 14,000MW due to multifarious constraints. Additionally, the total demand varies from 12,000MW in winter to 18,000MW in extremely hot months of summer. Consequently, the system faces acute energy shortages of upto 6000MW around the year**[1]**.Due to less supply of electrical energy, there is a daily load shedding of about 6 to 8 hours in urban areas and 12 to 16 hours in rural areas. This load shedding creates bad impact on operation of factories, everyday life of citizens and specially the education level of young generation living in rural areas of the country. In order to facilitate villagers with modern education and promote computer literacy among the youth, there is a need of computer labs in each and every educational institute situated in the premises of rural areas. This can be possible only when continuous electrical energy is supplied to these educational institutes, in the working hours.

Khyber Pakhtunkhwa has substantial potential of renewable energy resources such as biomass, wind, geothermal and solar. Among these resources, solar energy is best option to provide electricity to the rural institutes of Khyber Pakhtunkhwa, due to greater solar radiations. The Solar power requires less maintenance cost, though it has high initial implementation cost. Implementing solar system for rural institutes will help to educate villagers with modern computer knowledge.

In the proposed research project, the development of Solar Power and its effectiveness for educational institutes in rural areas of Khyber Pakhtunkhwa has been analyzed.

2. Literature Survey

Different researchers have carried out different researches related to this research project.

[2] Mahmud (2011) discussed the impact of the implementation of solarhybrid system which was installed at primary school in Sabah, Malaysia. The target of this project was to provide renewable electricity to those rural

areas in Sabah, where there was no grid connected electricity. In these areas there was the diesel generated electricity. The project analyzed the user's experience and economical aspects of the solar system and concluded that the renewable energy was the best option to provide electrical power supply to the educational institutes of rural areas than the diesel generated electricity. The project was also very beneficiary in making the lifestyle of the teachers and students more comfortable and providing the learning environment in these rural areas. The analysis of the system showed that this system could produce reliable power supply for educational institutes of these rural areas.

[3] Hassan and khan (2012) discussed the Global warming due to greenhouse gas emission in Bangladesh. The Generation of electricity from the alternative sources has become the necessity for Bangladesh. In Bangladesh, the rural areas population is about 75% of its total population and only about 30% of the rural areas have access to the grid connected electricity. The best solution of this problem is to introduce solarsystems for the rural areas in off-grid areas and to introduce solar grid hybrid system for the rural grid areas. He calculated the cost of energy for areas using solar PV in the grid and non grid areas. The purpose of the paper is to highlight the benefit of introducing solar PV both in grid and non grid areas to reduce the pressure on the existing grid network and to save money in terms of laying transmission and distribution network.

[4] Hutzel, William, man and David (2004) developed a remotely accessible solar energy laboratory developed for real-time experimentation using solar heating and photovoltaic equipment that is physically located at Purdue University. Indiana high school students were the first customers for this on-line resource. This project has been helping science teachers meet new state science standards from the Indiana Department of Education. Remotely accessed labs are becoming popular as they offer the opportunity for large numbers of students to learn because these are working at electrical energy using easily available solar system. The cost of expensive laboratory equipment is easier to justify if it can be widely used.

[5] Hui, Cheng and Hong (2010) proposed that while designing the solar power generation system, the user must consider not only the needs of the load and also the price of the solar cell, weight, annual power generating capacity (APGC) and the maximum power. It is an important task to find the power generation system with many parameters. Therefore, he presented an estimation method based on the extension theory. This estimation method can be the best and quick method for the selection of optimal solar power system. He proposed the method not only to provide a useful estimated tool for the solarsystem engineers, but also to supply the important reference with the installation of solarsystems to the consumer.

[6] Nava raj (2004)discussed that the cost of ruralelectrification is high and that's why the utilities fear to extend their services in the ruralarea. Due to high cost and significantly low benefit, the benefit cost ratio (BCR) is considerably low and sometimes less than unity in case of ruralelectrification schemes. This paper demonstrates a very simple method of controlling the cost of the ruralelectrification in one hand and at the same time improving the benefit for the utility by using solar PV system. The solar PV system provides the rural electrification in such a better way that it reduces the cost and gets the considerably more benefit.

3. Proposed Mechanism

In this research work, load of educational institutes of rural areas of KPK, Pakistan will be calculated and then solar PV system for the load will be designed and its cost effectiveness will be compared with the already installed power supply system.

Average Electric Power Supply Schedule for Educational Institutes in Rural Area of KPK.

There are 2 seasons in year, summer and winter. In summer, the school timing is different than winter. Here is the summarized comparison of school timings of both seasons and the WAPDA(Water And Power Development Authority)supply schedule in rural institutes of KPK in the form of tables and graphs.

Power Schedule for summer

School timing in summer is 07:00am to 12:30 pm and so the total School duration in summer is 05:00 hours. There is an average 03:30 hour Load shedding in school time and average WAPDA supply is for 01:30 hours.

Graphically the electric power supply schedule in summer season is shown in Fig 1.

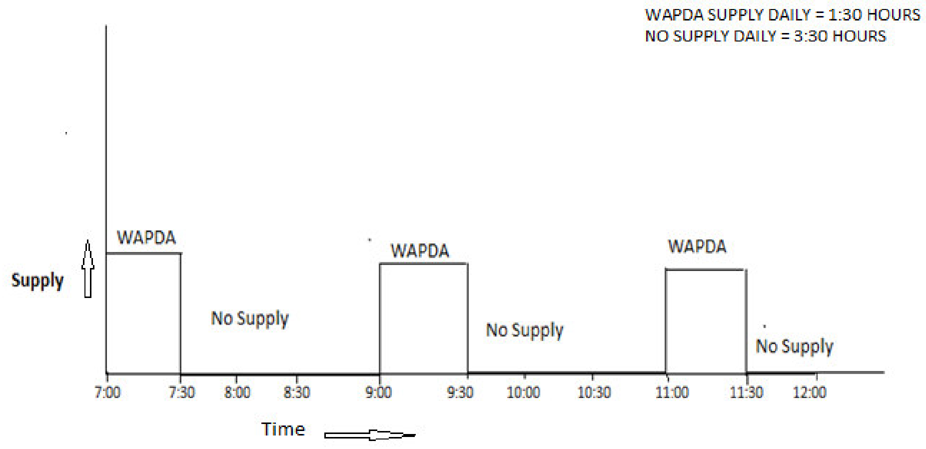

Fig 1WAPDA timings in institutes of rural areas in summer

Power Schedule for winter

School timing in winter is 08:30am to 02:30 pm and so the total School duration in summer becomes 06:00 hours. There is an average 04:00 hours Load shedding in school time and average WAPDA supply is for 02:00 hours.

Graphically it is shown in Fig 2

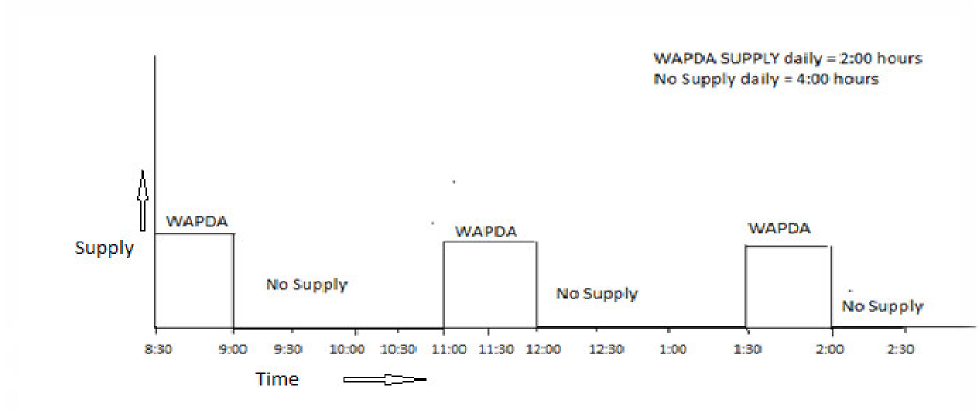

Fig 2WAPDA timings in rural areas institutes in winter

LOAD CALCULATION FOR SCHOOLS

The main aim of my project is to introduce the Solar PV System for the computer labs in rural areas of KPK so that to improve the literacy level in these areas. For this purpose visit has been paid to the different schools in these areas and has taken one average school of each category as High, Middle and Primary school respectively. All these schools are located in one of the rural areas of KPKi.eLakkiMarwat. We visited each school and got data about number of students, number of classrooms, number of fans and suitable number of computers required for improving computer literacy rate in these schools. This data of each school is summarized as technical data, load required for the computer labs operation and fans loads. Finally the overall average load in all schools of rural areas is calculated for each school in tabular form.

Table 1 Technical Data of all schools

Parameters	High School	Middle School	Primary School
No of Students	300	180	370
No of fans	20	15	15
No of energy saver	20	16	16
No of copmuters	30	18	25
No of computer classes daily	3	3	4
Time of each class(hours)	1:30	1:30	1
Computer usage daily (hours)	4:30	4:30	4
Computer usage weekly (hours)	22:30	12	16
Computer usage monthly (hrs)	64:30	18	64
Computer usage in winter (hrs)	193:30	54	192
Computer usage in summer(hrs)	387	162	384

Table 2 Load calculation of all schools

Parameters	High School	Middle School	Primary School
No of computers	30	18	25
One computer load(watt)	300	300	300
Computer load daily (kw)	300*3 = 9	300*18= 5.4	300*25= 7.5
Energy units daily (kwhr)	9*4.5 = 40.5	5.4*4.5= 24.3	7.5*4= 30
Energy units weekly (kwhr)	40.5*5 =202.5	24.3*4= 97.2	30*4= 120
Energy units monthly (kwhr)	202.5*4=810	97.2*4= 388.8	120*4= 480
Energy units in summer (kwhr)	810*3=2430	388.8*3= 1166.4	480*3= 1440
Energy units in winter (kwhr)	810*6=4860	388.8*6= 2233	480*6= 2880
No of fans	20	15	15
One fan load(watt)	100	100	100
Fans load (kw)	20*100= 2	15*100= 1.5	15*100= 1.5
Fan energy units daily (kwhr)	2*5= 10	1.5*5 = 7.5	1.5*5= 7.5
Fn energy units weekly (kwhr)	2*29= 58	1.5*29= 43.5	1.5*29= 43.5
Fan energy units monthly(kwhr)	2*121= 242	1.5*121= 181.5	1.5*121= 181.5
Fan energy units in summer(kwhr)	2*3(121)= 744	1.5*3(121)= 558	1.5*3(121)=

			558
Fan energy units in winter(kwhr)	2*2(121)= 484	1.5*2(121)= 363	1.5*2(121)= 363
Total load daily(kw)	9+2= 11	5.5+1.5= 7	7.5+1.5= 9

Fig 3 shows the daily average load profile for rural educational institutes of kpk graphically. From Graph it is clear that daily average load profile for high school is11 kW, for middle school is 7 kW and for primary school is 9 kW.

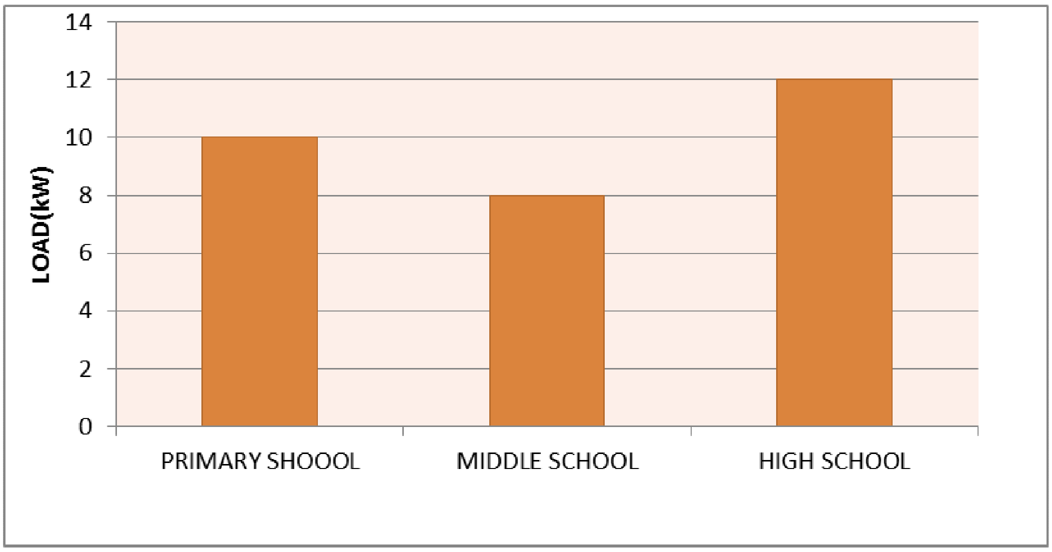

Fig 3 Daily average load profile for rural educational institutes of KPK

Calculation of Computer Average load of schools in rural Areas:

Table 3Computer Average load of schools in rural Areas

Parameters	High school	Middle School	Primary School
No of Schools in kpk	1697	2526	22398
No of schools in rural areas of kpk	950	1700	18000
Avge load in 1 school daily(kwhr)	40.5	24.3	30
Avge load in all rural schools daily(kwhr)	38475	41310	540000
Avge load in 1 rural school weekly(kwhr)	202.5	97.2	120
Avge load in all rural schools wekly(kwhr)	192375	165240	2160000
Avge load in 1 rural school monthly(kwhr)	810	388.8	480
Avge load in all rural schools monthly(kwhr)	769500	660960	8640000
Avge load in 1 rural school in summer(kwhr)	2430	1166.4	1440
Avge load in all rural schools in sumer(kwhr)	2308500	1983220	259200000
Avge load in 1 rural school in winter(kwhr)	4860	2333	2880

Avge load in all rural schools in winter(kwhr)	4617000	396600	51840000

Fig 4 shows total load profile of educational institutes in rural areas of KPK graphically. From graph it is concluded that total load for all high schools in rural areas of KPK, for middle schools and for primary schools is represented in gaga watts(GW).

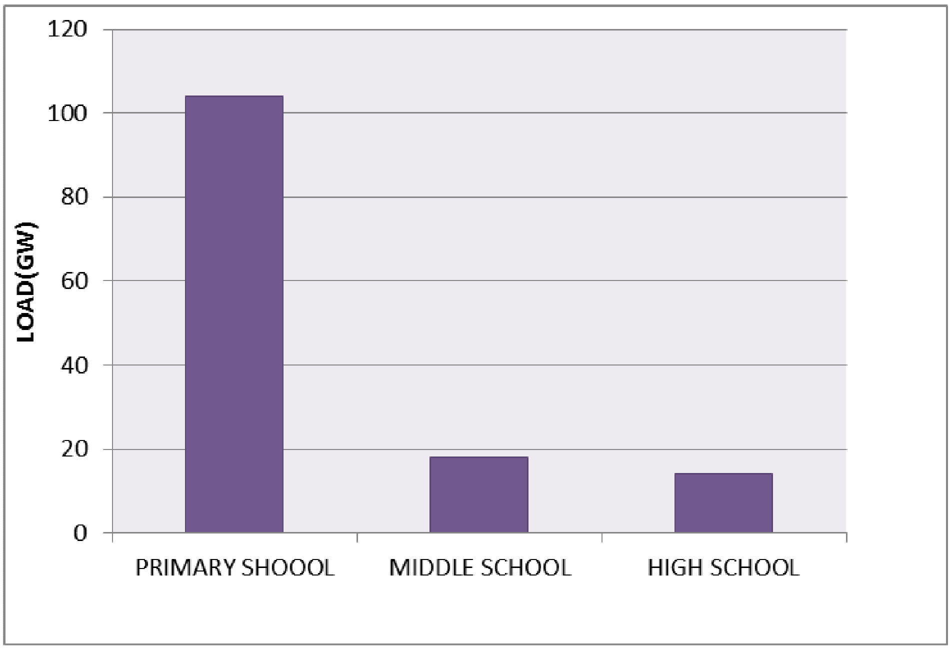

Fig 4 Total load profile of educational institutes in rural areas of kpk.

Calculation of MonthlyWAPDA Bill in Educational Institutes:
Table 4 calculation of monthly bill of all school

Parameters	High school	Middle School	Primary School
Energy units of computers monthly	810	388	480
Energy units of fans monthly	242	182	182
Total units	10527	570	662
Trrif range(Rs) per unit	5.79 to 19.43Rs	5.79 to 12.33Rs	5.79 to 12.33
Total tarrif after calculation(Rs)	13157	5530	6665
G.S.T(Rs)	643	370	425
Total bill per month(Rs)	1157+643=31380 0	5530+370=5900	6665+425=7090

SOLAR DESIGN

Solar Irradiation data in Pakistan

Table 5 Mean Monthly Summer Sunshine Hr/Day 1980- 1990

Station. N.	Summer	Station. N.	Summer	Station. N	Summer	Station. N.	Summer
Astore	8.2	Dalbandin	10.1	D.I. Khan	8.7	Lahore	8.9
Chilas	8.4	Kalal	10.3	Parachinar	8.9	Multan	8.6
Gilgit	8.5	Nokkundi	9.5	Peshawar	8.8	Hyderabad	9.3
Gupis	8.6	Quetta	10.4	Charsadda	8.6	Jaccobabad	8.9
Skardu	8.6	LakkiMarwat	9.5	Islamabad	9.2	Karachi	7.6
Nawabshah	9.0	Sargodha	8.9	Chaman	10.0	Bannu	9.8

Source: Pakistan Meteorological Department, Karachi

Table 6 Mean Monthly Winter Sunshine Hr/Day 1980- 1990

Station. N.	Winter	Station. N.	Winter	Station. N	Winter	Station. N.	Winter
Astore	4.4	Dalbandin	7.5	D.I. Khan	7.9	Lahore	7.6
Chilas	5.2	Kalal	7.7	Parachinar	7.4	Multan	7.8
Gilgit	5.0	Nokkundi	7.1	Peshawar	6.7	Hyderabad	9.1
Gupis	5.2	Quetta	8.2	Charsadda	6.8	Jaccobabad	8.3
Skardu	5.4	LakkiMarwat	8.3	Islamabad	7.0	Karachi	8.9

Source: Pakistan Meteorological Department, Karachi

Table 7 Mean Annual Sunshine Hr/Day 1980- 1990

Station. N.	Annual	Station. N.	Annual	Station. N	Annual	Station. N.	Annual
Astore	6.5	Dalbandin	8.6	D.I. Khan	9.1	Lahore	8.4
Chilas	6.5	Kalal	8.8	Parachinar	8.3	Multan	8.3
Gilgit	6.6	Nokkundi	8.5	Peshawar	7.9	Hyderabad	9.2
Gupis	6.8	Quetta	9.15	Charsadda	7.8	Jaccobabad	8.7
Skardu	6.3	LakkiMarwat	9.3	Islamabad	8.3	Karachi	8.1

Source: Pakistan Meteorological Department, Karachi

Looking at the tables, our areas of interest are Lakkimarwat, Charsadda, Peshawar, D.I Khan and Bannu as our research work is related with the rural areas of KPK. In these areas of KPK, the maximum sunshine areas are Lakkimarwat, D.I.Khan and Bannu while Charsadda and Peshawar are the moderate sunshine areas.

SOLAR PARAMETERS FOR THE REQUIRED LOAD ALONG WITH CAPITAL COST

Parameters	Price		
	High School	Middle School	Primary School
Solar Panel 12kw	660000	440000	550000
Battery 150 Ah 12v	264000	176000	220000
Charge Controller 50 Amp	70000	45000	55000
Inverter 15kw 350 VDc	600000	400000	400000
Panel Structure	60000	40000	50000
junction box	40000	250000	30000
DC cable 25mm	7200	4800	6000
Transportation	10000	8000	9000
Installation	75000	60000	60000
Total	1786200	1198800	1380000

The graphical representation of these entire tables is shown in fig 5 in which the cost of each school required load Solar PV System is represented. From this graph it is concluded that solar capital cost for primary school load is Rs 1.38 5illion, for middle school load is Rs1.19 million and for primary school load is Rs 1.79 million.

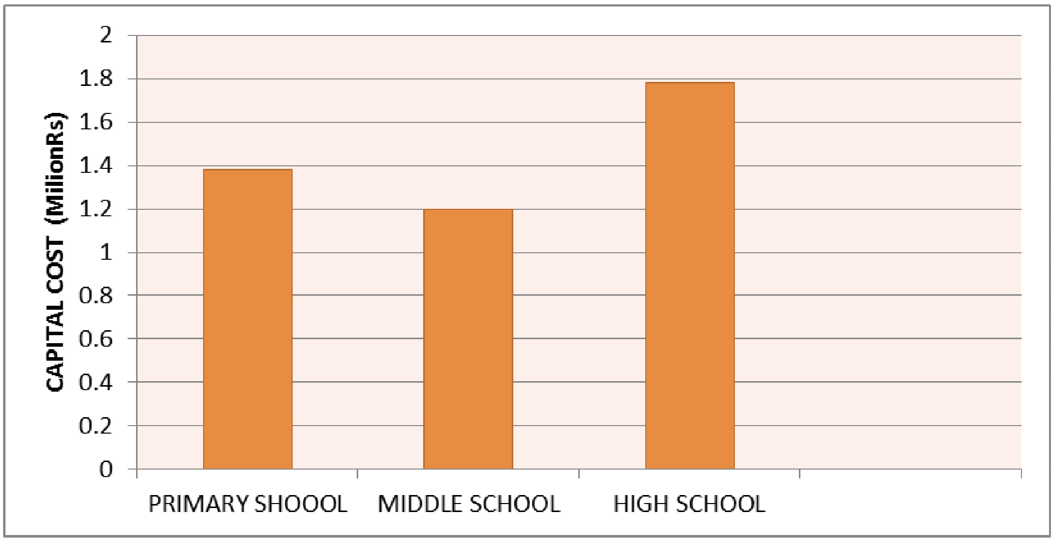

Fig 5 Solar capital cost for each educational institutes in rural areas of KPK

4. RESULTS AND DISCUSSION

This section analyzes the results of the research in which there is the comparison of current electric energy supply scheme and that of Solar PV System for the computer labs in educational institutes of rural areas in KPK.

The main factor involved in this research is the economical aspect of improving computer literacy that can be determined by the analysis of cost effectiveness of Solar PV System, comparing the WAPDA system, Solar system for the life time of 25 years and finding the recovery time for the capital cost of Solar PV System.

Cost effectiveness of Solar PV System

Total Cost Effectiveness of Solar PV System has two approaches.

1) Average Consumer Analysis Approach:
2) Market Segment Analysis Approach:

Average Consumer Analysis Approach

This approach depends upon Time Dependent Valuation that is time varying measure of energy used. The energy generation, transmission and distribution losses are included in the measuring variables in Time Dependent Valuation.

Market Segment Analysis Approach

This approach calculates the cost effectiveness of Solar PV System based on utility bills savings that depends upon utility rates. Electrical retail rates increase is the important factor that should also be in consideration. Research team has assumed that retail rates have been increasing every year by about 2.5%.

Comparison of WAPDA and Solar PV System for life time of 25 years

The Solar PV System is installed for the life time of 25 years. Here is the complete comparison of WAPDA electric supply cost and Solar PV cost for 25 years for high , middle and primary schools of rural areas in tabular form as:

Table 8Comparison of WAPDA and Solar PV System for life time of 25 years

Parameters	High school	Middle School	PrimarySchool
WAPDA cost per month(1 school)in Rs	13800	5900	7090
WAPDA cost per year (1 school) in Rs	13800*12=165600	70800	85080
WAPDA cost for 25 years in Rs	165600*25=4140000	1770000	2127000
Solar capital cost for 25 years in Rs	1786200	1198800	1380000
Solar economic benifit in 25 years(1 school) in Rs	4140000-1786200=2353800	571200	747000
Solar economic benifit in 1 year in Rs	2353800/25= 94152	22848	29880
Solar economic benifit in 1 month in Rs	94152/12= 7846	1904	2490
No of all rural schools	950	1700	950
Solar economic benifit in 1 month(all schools) in Rs	950*7846= 7453700	3236800	44820000

Fig 6 shows the net monthly profit using Solar PV System in each one school after comparing electrical energy consumption by WAPDA and Solar PV System graphically.

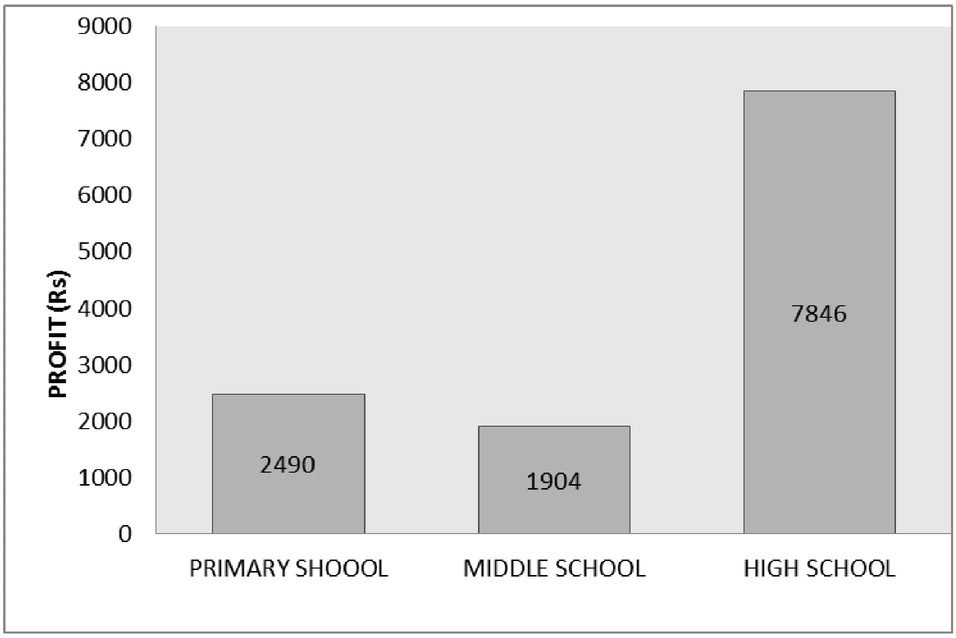

Fig 6 Net Monthly Profit using Solar PV System graphically

Recovery Time of Capital Cost of Solar PV System

Capital initial cost of Solar PV System is very high but this capital cost stands for 25 years so here we have calculated this capital cost recovery time for each school in tabular fom as:

Table9Recovery Time of Capital Cost of Solar PV System

Parameters	High school	Middle School	Primary School
Bill per month in Rs	13800	5900	7090
Bill per year in Rs	13800*10= 138000	5900*10= 59000	7090*10= 70900
Solar capital cost in Rs	1786200	1198800	1380000
Cost recovery time(in years)	1786200/13800= 13	1198800/59000= 18	1380000/70900= 19

Fig 7 shows solar cost recovery time of each school in rural areas of KPK graphically.

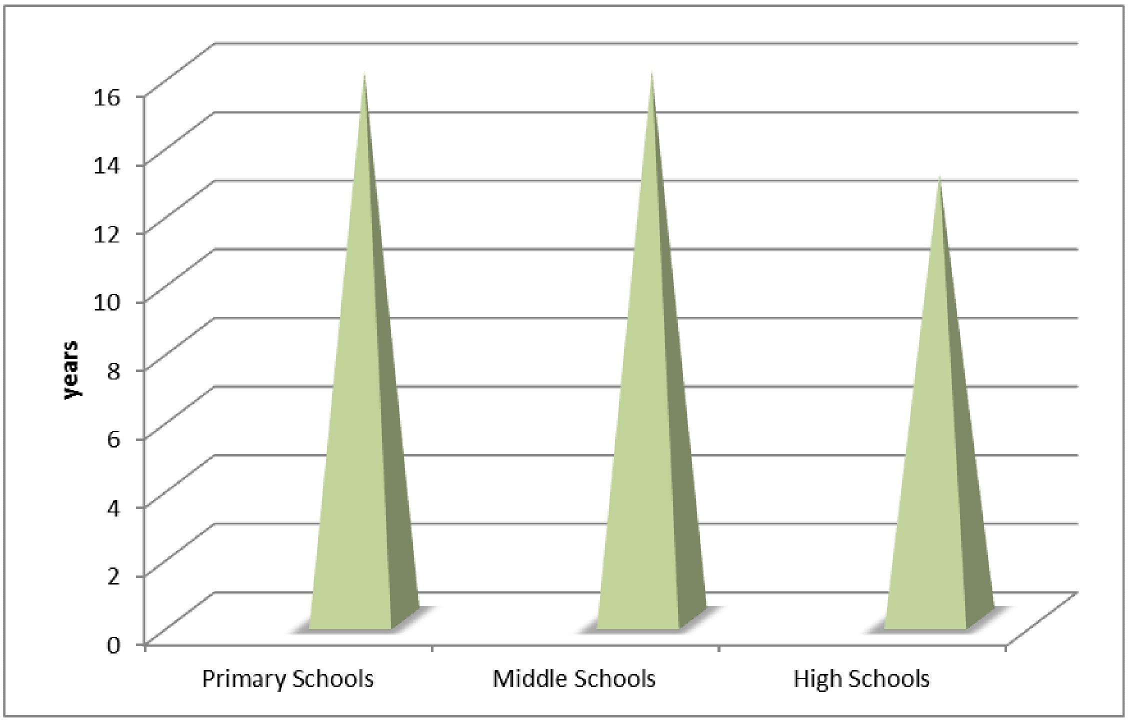

Fig 7 Solar cost recovery time of each school in rural areas of KPK

5. Conclusion

Different educational institutes in rural areas of KPK were visited and their study routine was analyzed. There is three to half and three hours load shedding in school timing of five hours in school timing in summer while four to half and four hours load shedding in school timing of six hours in winter according to our observation and calculation. Literacy rate improvement requires the uninterrupted power supply to computer labs. The current WAPDA supply system for these areas is examined which is insufficient for the operation of computer labs. According to the WAPDA tariff rules, the electricity consumption for operating computer labs in these schools have been calculated if there is uninterrupted electric power supply. The problem of paucity of power supply to these labs that can only be solved with the use of renewable energy resources. Among these resources, Solar PV System was selected because of its pleasant effects. Solar PV System installed in these areas is not only the cause of improving the computer literacy rate but it is also cost effective. The market price of Solar parameters for the required load of each school was calculated separately. It is also concluded that initial cost of Solar PV System is very high but maintenance cost of this system is very low. After analyzing the costs of conventional power supply and that of Solar PV System designed, it is concluded that Solar PV System is much more cost effective compared to the installed power supply system in rural areas of Khyber Pukhtunkhwa, Pakistan.

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