FEASIBILITY VALUATION FOR SHIFTING AN EDIFICE TO ON-GRID SOLAR POWER MODELED BY COST-BENEFIT ANALYSIS, CARBON FOOTPRINTS, DESIGN AND LEVELIZED COST OF ENERGY: A CASE STUDY OF NEW CAMPUS BAHRIA UNIVERSITY ISLAMABAD.

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ABSTRACT*: Pakistan is an unfortunate victim of a colossal energy predicament, facing a concurrent dilemma of soaring prices of fossil fuels. It is becoming increasingly difficult for the country to meet the growing demand of electricity. Taking Bahria University Islamabad as a case, the current study aimed to make design feasibility, calculate carbon footprint from electricity consumption by grid electricity and generators, levelized cost of electricity, cost-benefit analysis of installation of solar photovoltaic system and introducing the concept of net metering. The study reveals that annual carbon footprints of the building from grid electricity are 296131.67 (kgCO_2e), 57640 (kgCO_2e) of carbon footprints are added by the generators used to provide electricity annually; whereas the solar panels have zero carbon emissions. The Net Present Value of solar photovoltaic (PV) system installation is Rs.28,478,834 which will result in a positive cash flow and internal rate of return (IRR) is 26.9%, which is greater than investment in bank saving for which the discount rate is considered at 6.5%. The Cost Payback Time for the investment, only 4.4 years, is very cost effective. The levelized cost of electricity is 24.7 Rs/kWh that is fixed solar electrical cost that remains the same throughout the lifetime of the solar plant. The proposed mix energy system contains 59% of fossil fuel energy, 11% of solar energy and 30% of generator. Moreover, the concept of net metering is proven to be an influential parameter to encourage the use of solar PV system. Categorically, all of the acquired results and present growing energy demand calls for investment in solar energy.*

INTRODUCTION

Global energy crisis has reached to an alarming stage owing to greater utilization than production of energy resources, which is resulting in escalating prices and more burdens on finite natural resources such as fossil fuels and oil. Pakistan has been a victim of an ever-increasing energy crisis as well as adverse effects of climate change. The intermingling of the two arises from Pakistan's energy production sources and usage. The reported electrical generation capacity was 95TWh in 2012 whereas electricity consumption was 76.7TWh showing 17.3% line losses [1]. As the electricity demand is increasing day by day in Pakistan, it will grow by more than eight times from 19.5 million kilowatt in 2005 to 162.5 million kilowatt in 2030 [2]. Renewable energy sources like solar, wind, water-based energy generation and biofuels are considered as prosperous, sustainable and secure energy alternatives for the entire world [3]. Choosing the best design for the panels installation considers many options like choosing the best alternative for normal silicon-based p-n junction solar cells replaced by organic solar cells giving additional 10% energy-conversion efficiency [4]. Furhermore, the opimization in solar system is done using a stepper motor and light sensor in order to track the sun [5]. Electricity generation provides 18,000 terawatt-hours of energy a year, around 40% of human's total energy use and produces more than 10 gigatonnes of carbon dioxide every year. Solar energy is one of the sources that basically involve a move to carbon-free sources of electricity [6]. A study examined the economic feasibility of installing and utilizing solar panels at a large scale suggests that with the positive net present value and internal rate of return, the investment of solar panels could be beneficial [7]. To correctly assess the benefits of installation of solar panels the capital investment into the setup must be duly balanced or outweighed by the external benefits, and cost pay-back opportunities. Financing options need to be dealt with and rebates from government should be availed to lower the economic cost [8]. The overall analysis, therefore, needs to incorporate discounted cash flow analysis of entire financial and social costs [9]. Additional aspects like environmental impacts are mandatory in consideration of final decision. The general cost of running the system and environmental concern are important factors in decision making [10]. The levelized cost of electricity (LCOE) generation is ranking tool to assess the cost effectiveness of different energy generation technologies [11] hence, helps make comparisons. Since, solar energy is the most abundant, inexhaustible and clean of all the renewable energy resources till date [12]. In terms of available solar energy, Pakistan is amongst the richest countries in the world, having an annual global irradiance value of 1900–2200 kWh/m^2 [13]. Presently, Bahria University, Islamabad Campus (BUIC) is using utility power and also diesel generator to backup power outing. The study has been carried out to propose a suitable design of grid interactive rooftop solar PV system for new campus, calculate the carbon footprints from grid and high-speed diesel, undertake the cost-benefit analysis of installation and operation of solar power system for electricity generation including the cost payback time and finally, to calculate the levelized cost of energy associated to it.

MATERIAL AND METHOD

The undertaken study was carried out in Bahria University Islamabad –New campus as a case for determining the feasibility assessment of solar power. The study is divided into five following parts: design, carbon foot prints, cost benefit analysis, levelized cost of energy and net metering.

a) **Study area**

Bahria University Islamabad Campus is located in E-8 sector of Islamabad Pakistan within the coordinates of $33^0$42'52. 99"N and $73^0$01'45.43"E. The university has three main campuses namely, old campus (OC), new campus (NC), extended campus (XC). The selected campus building has three floors and the total cover area of NC is 105835sft.

b) Data

The data acquired for the conduction of study included building's architectural map, roof size and shaded area of roof. Further, electricity bills for the year April 2014-March 2015 and fuel consumption of generators per year along with operation and maintenance cost was also determined that helped us in making the feasibility model and to calculate the overall project cost and energy savings.

Additional data for the calculations of Carbon Footprint & Cost benefit Analysis have been gathered from different sources, which are shown in Table 1

Table 1: Secondary Data Sources

Data	Value	Source
Emission factor for consumption of grid electricity.	0.75737 kg CO_2/kWh (inclusive of indirect emissions)	International Energy Agency 2010
Emission factor for high speed diesel generators	2.64 kg CO_2/liter	Emission Factors for Refined Petroleum Products 2015
Discount rate	6.5%	State Bank of Pakistan 2015

METHODS

a. Design

The system type that has been proposed for new campus is hybrid of grid and solar PV (on grid system). This system is likely to ensure complete compliance and adequacy to the design parameters. The offered system has been designed based on the current irradiance. The shaded area of the roof is excluded, inverters to be mounted beneath the mounting structure, azimuth is 0 degrees and tilt is 21 degrees

Figure 1: Study Area Map

b) .Calculation of Carbon Footprint (CF)

In this study, it may be highlighted here that the "activity" under observation for which CO_2 emissions are based is the consumption of grid electricity and the fuel consumption of generators. The Carbon Footprint for grid electricity usage is calculated by formula:

$$\mathbf{CF} = \mathbf{Use}\left(\frac{\text{kWh}}{\text{month}}\right) \times \mathbf{EF}\left(\frac{\text{kgCO}_2\text{e}}{\text{kWh}}\right)$$

where,

Use = units of electricity consumed per month per person

EF = emission factor for consumption of grid electricity.

Similarly for calculation of CF for generator the following formula can be used [14].

$$\mathbf{CF} = \mathbf{Use}\left(\frac{\text{liters}}{\text{year}}\right) \times \mathbf{EF}\left(\frac{\text{kgCO}_2\text{e}}{\text{liter}}\right)$$

b. Cost-benefit analysis

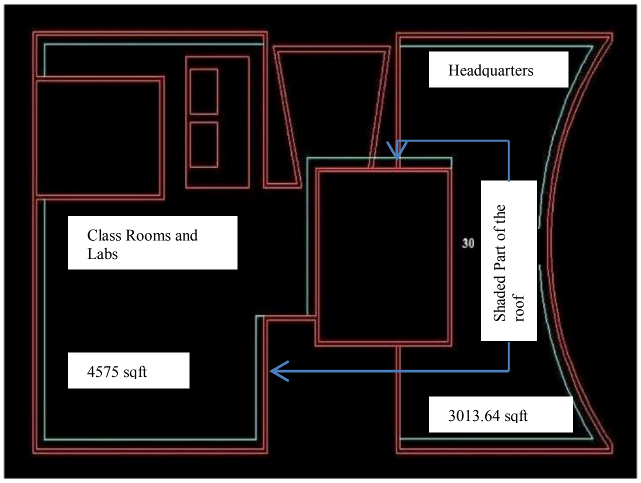
The CBA undertaken includes an extensive feasibility analysis and Cost-Payback-Time (CPT). Feasibility analysis for this study includes components such as:

(i) **System, size and cost**: system size**,** inverter and other equipment**,** installation and other fees.

(ii) **System life and maintenance:** system life expectancy, yearly depreciation of system efficiency, yearly maintenance cost.

(iii) **Incentives and rebate**: Rebate per watt, Revenue per watt [15].

Since Pakistan's Renewable Policy (2006) does not have any provision for incentives (rebates) or tax benefits to solar powered edifices, the last component (IV) does not apply to the present study. However, to complete the theoretical presentation we report it here.



(iv) **Financing**: If the university decides to borrow money to meet the initial cost of installation of solar PV system through loans then it has to acquire additional cost in the form of interest payments. This component thus includes the following information: loan interest rate, loan period and monthly payment.

(v) **Analysis of feasibility indicators**

a) Internal rate of return (IRR)

$$IRR = CFo + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \frac{CF_3}{(1+r)^3} + \ldots + \frac{CFn}{(1+r)^n} = 0$$

Where, CF = cash flow, r = rate of return, n = year from initiation of project (installation of solar panels)

b) Net present value (NPV)

$$NPV = \sum_{t=0}^{n} \frac{Rt}{(1+i)t}$$

Where, t = the time of cash flow, i = discount rate (that is 6.5 % as quoted by State Bank of Pakistan), Rt = net cash flow i.e. cash inflows – cash outflows

c) Cost pay-back time

$$\mathbf{CPT} = \frac{\mathbf{Cin}}{(\mathbf{Cs} - \mathbf{Com})}$$

Where, Cin = installation cost, Cs = annual cost saved, Com = annual cost of maintenance [16].

d) Levelized cost of energy

$$LCOE = \frac{\sum_{t=0}^{T}(I_t + O_t + M_t + F_t)/(1+r)^t}{\sum_{t=0}^{T}E_t/(1+r)^t} = \frac{\sum_{t=0}^{T}(I_t + O_t + M_t + F_t)/(1+r)^t}{\sum_{t=0}^{T}S_t(1-d)^t/(1+r)^t}$$

Where, It = the capital cost expenditures in year t [Rs], O &Mt= the operating and maintenance costs in year t [Rs], St=Yearly rated energy output for t [kWh/year], r= is the discount rate [%], T= is the lifetime of the project and, d= degradation factor [%] [17].

RESULTS

Proposed Design

A suitable design is based on the location and its size for the installation. The size of the roof determined the project size and suitable design for which the roof size was measured. As the New campus is further divided into two blocks A & B, for each side the roof was measured separately illustrated in Table 2.

Figure 2: Building's roof sketch for Solar PV panels installation

Table 2: Roof measurement and project size

Roof	Size	Power output
Roof size of Block A	3013.64 ft^2	18.86 kW
Roof size of Block B	4575 ft^2	28.5 kW
Total roof size	7588.64 ft^2	47.36 kW
*including other roofs		Approx. 55kW

Since the panel size and number are based on roof measurements, apart from above mentioned two roofs small separated roofs were also included as a part of the building. Therefore, the approximate size of the project proposed is 55 kW. The proposed design is roof mounted panels having a panel size of 250 W each. The structural support frame will be required for each panel and the direction of these panels will be towards south .It should be noted here that the roof size measured excludes the areas that are shaded. The inverters will be mounted beneath the mounting structure or on the third floor because the nearer the invertor the more efficient it works. Environmental monitoring and remote monitoring will also be included in this design that will help understand the units produced by the panels and amount of irradiation received by the panels. For this purposes a separate room would be required for the installation of computer system linked to the monitoring device.

Carbon foot prints

Table 3 depict the units of electricity used per kWh; retrieved from the WAPDA electricity bills of our selected campus (NC) for the year April 2014 - March 2015, followed by their respective calculated carbon footprints in the last column. The carbon foot prints for generator have been calculated and shown in table 4

Table 3: April 2014 –March 2015; Grid Electricity

Months	Units(KWH)	Emission Factor	Carbon foot Prints of New Campus ($kgCO_2e$)
Apr-14	23000	0.75737	17419.51
May-14	37000	0.75737	28022.69
Jun-14	49000	0.75737	37111.13
Jul-14	38000	0.75737	28780.06
Aug-14	31000	0.75737	23478.47
Sep-14	37000	0.75737	28022.69
Oct-14	45000	0.75737	34081.65
Nov-14	36000	0.75737	27265.32
Dec-14	30000	0.75737	22721.1
Jan-15	26000	0.75737	19691.62
Feb-15	24000	0.75737	18176.88
Mar-15	15000	0.75737	11360.55
Total Sum	**391000**	**N/A**	**296131.67**

Table 4: Carbon foot print from generator

Annual fuel Consumption	Calculation	Carbon foot Prints of New Campus ($kgCO_2e$) per year
22000	22000 liters/year x 2.64 kg CO_2/liter	57640 $kgCO_2$ per year

A graphical representation of monthly unit consumption and carbon footprints of grid electricity is shown in figure 3.

At present, the total grid electricity units consumed by the new campus are 49000 kW, whereas the corresponding total Carbon Footprint of the year is 296131.67$kgCO_2e$ (Table 3). The maximum amount of units being used are through the months April –June, with June accumulating the greatest number of units at 49000 kW. Contrarily, the lowest consumption of units is in the months of August (31000 kW), January February and March. The general trend of the Carbon Footprint follows parallel to the consumption of the units of grid electricity. The average electricity consumption of the first quarter of the year (April-June) is 36333 units, similar to which the carbon footprint at its peak 37111.13$kgCO_2e$ in June and gradually decreases.

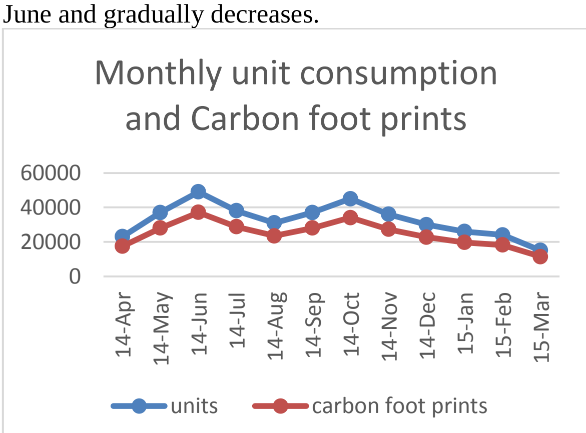


Figure 3:Monthly Unit Consumption and Carbon Foot prints

The high consumption of electricity can be linked with the relatively high average temperatures in Islamabad during these three months, thus the load on electricity is comparatively more. The decrease in trend is representing the summer break with minimum utilization of electricity in August. Although the temperature increase in these three months; coupled with greater usage of appliances such as fans, air conditioners and refrigeration to counteract longer hours of electricity load shedding in the summer months account for greater consumption of electricity units. This is evident from the graph (fig. 3), which shows decrease in electricity units whereby in September this increased to 37000 kWh with carbon footprint of 28022.69$kgCO_2e$. This trend continues on to the forthcoming months of October, November and December. The consumption and Carbon Footprint value increases, the electricity consumption changes with the onset of December; the electricity units consumption in October are recorded as 45000kWh with a Carbon Footprint of 34081.6 5 $kgCO_2e$, following a continuous downhill of all variables, electricity consumption and carbon emissions. There is a steep decrease in the electricity units consumed between Novembers – March leading to the lowest Carbon Footprint calculated throughout the year from 27265.32 to 11360.55 $kgCO_2e$. The decreasing trend is related to changing season moving towards winter with less consumption of electricity, as air conditioners are not used. Additionally, winter break in the month of January is also the reason of decrease in trend.

Cost benefit analysis

Table 5: Total Initial System Cost

Equipment	Quantity	Price
Solar Panels	220	4,492,125
Inverter	1	786,250
Remote Monitoring	1	124,144
Environment Monitoring	1	430,369
Computer	1	93,750
Mounting Structure	55,000	687,500
Cables	1	124,088
System Accessories	1	120,625

Site Services	1	631,750
Logistics	1	100,000
Site Management	1	112,359
Total cost		**7,702,959**

Table 6: Parameters to Estimate System Costs and Benefits

System Size	55000	Watt
Cost of Installation Other Fees*	7,702,959	Rs.
System Life & Maintenance		
System Life Expectancy	25	Years
Yearly depreciation of system efficiency**	0.99	%
Yearly Maintenance and Operation Cost***	99,444	Rs.
Incentives & Rebates****		
Rebate per watt	N/A	N/A
Revenue per watt	N/A	N/A

(Source: Based on companies' estimates.)

**Other Fees include transportation cost and electrical inspection charges, the latter varies from Rs. 1000 – 5000, however are refundable on the condition that installation of panels is made.*

*** The system efficiency depreciation per year is quoted at 0.99 % according to a study on levelized cost*

**** Yearly maintenance and operation costs doesn't include the cost of invertor and it varies from year to year.*

*****There are no incentives or rebates for solar powered households Pakistan's Renewable Policy (2006).*

Currently, the consumption is about 66% from the grid electricity and 34% from generators while on the other hand the proposed energy mix estimates that the solar power will provide the campus with 11% of energy for usage. The less energy contribution is due to the small size of project that is 55000 Watts whereas the sanction load of grid is 679 kilo Watts and the production capacity of generator is 400 kilo Watts. This 11% production of the solar system will provide about Rs 1,576,901 savings in the first year that will reach up to Rs 7,886,668 in the 25th year. To sum up, the cost benefit analysis signifies the financial viability of the solar photovoltaic system for the new campus understudy. All the capital analyzing tools show a positive signal for the investment. It must be underscored here, that these are only financial benefits; we must for a project add the environmental benefits that come under the environmental electricity savings and reduction in carbon footprint.

Table 7: Levelized cost of energy.

It	**Ot +Mt**	**It+Ot+Mt**	**t**	**(It+Ot+Mt)/(1+r)t**	**St**	**(1-d)t**	**St(1-d)t**	**St(1-d)t/(1-r)t**
7702959		7702959	0	7702959		1	0	0
7702959	99443.52	7802402.52	1	7326199.549	82870	0.99	82041.3	87744.70588
7702959	98548.53	7801507.53	2	6878271.532	82124	0.9801	80489.73	92069.81315
7702959	97661.59	7800620.59	3	6457736.672	81385	0.970299	78967.78	96608.45105
7702959	96782.64	7799741.64	4	6062919.278	80625	0.960596	77448.05	101336.0712
7702959	95911.59	7798870.59	5	5692246.193	79926	0.95099	76008.83	106366.7764
7702959	95048.39	7798007.39	6	5344240.522	79207	0.94148	74571.82	111610.5034
7702959	94192.95	7797151.95	7	5017515.74	78494	0.932065	73161.54	117112.0403
7702959	93345.22	7796304.22	8	4710770.156	77788	0.922745	71778.46	122885.6795
7702959	92505.11	7795464.11	9	4422781.725	77088	0.913517	70421.22	128943.3745
7702959	91672.56	7794631.56	10	4152403.172	76394	0.904382	69089.36	135299.156
7702959	90847.51	7793806.51	11	3898557.412	75706	0.895338	67782.48	141967.7572
7702959	90029.88	7792988.88	12	3660233.263	75025	0.886385	66501.03	148966.6354
7702959	89219.61	7792178.61	13	3436481.402	74350	0.877521	65243.69	156310.2873
7702959	88416.64	7791375.64	14	3226410.588	73681	0.868746	64010.06	164015.7989
7702959	87620.89	7790579.89	15	3029184.101	73017	0.860058	62798.88	172098.76
7702959	86832.3	7789791.3	16	2844016.411	72360	0.851458	61611.48	180582.5984
7702959	86050.81	7789009.81	17	2670170.04	71709	0.842943	60446.61	189484.8924
7702959	85276.35	7788235.35	18	2506952.625	71064	0.834514	59303.89	198826.449
7702959	84508.87	7787467.87	19	2353714.159	70424	0.826169	58182.1	208626.1673
7702959	83748.29	7786707.29	20	2209844.393	69790	0.817907	57081.73	218909.633
7702959	82994.55	7785953.55	21	2074770.408	69162	0.809728	56002.4	229700.9555
7702959	82247.6	7785206.6	22	1947954.332	68540	0.801631	54943.76	241025.472
7702959	81507.37	7784466.37	23	1828891.191	67923	0.793614	53904.66	252906.0887
7702959	80773.81	7783732.81	24	1717106.897	67312	0.785678	52885.57	265374.0815
7702959	80046.84	7783005.84	25	1612156.364	66706	0.777821	51885.35	278454.6613
			Sum =	102784487.1			**Sum=**	4147226.809
			LCOE=	**102784487.1/4147226.809**	=	**24.78 Rs/kWh**		

Levelized Cost of Energy

The amount of plant output over its life time and the initial cost of the plant are two important factors for determining the levelized cost of energy. Degradation factor 0.99% determines the changes in plant output per year as the plants efficiency decreases each year

The Table 7 depicts the calculations of levelized cost. The levelized cost of energy from the solar photovoltaic system provides information regarding the cost of unit that will remain same for the 25 years as compare to other utility electricity. The calculated levelized cost is 24.78 Rs/kWh, which is fixed solar electrical cost that remains the same throughout the life time of the solar plant whereas the cost of other utility electricity that would be purchased will escalate over the time.

Net metering

One of the emerging concepts that is being introduced in Pakistan but not being efficiently working is net metering. It provides the owner with monetary benefits as the units are sold back to the utility suppliers of electricity. Per unit cost is not defined in Pakistan and no such system has been established yet. According to National electric power regulatory authority it's only applicable to projects that are producing energy less than 1 mega Watt.

CONCLUSIONS

The results of the study revealed that the rooftop solar panels installation is considered as the most appropriate project as it doesn't require any separate land for installation of the project. The financial feasibility undertaken in the study for a system of 55,000W is evidently a profitable investment as the NPV calculation has a positive cash flow. The IRR of solar PV system installation is 26.9%, which is more beneficial than bank investment. Additionally, the cost payback time calculated is only 4.4 years with an increase in saving per year. The calculated levelized cost is Rs 24.7 which is fixed solar electrical cost that remains the same throughout the life time of the solar plant. A concept of net metering is new and most effective way of promoting investment in solar power by allowing investors to provide incentives for the energy they feed back into the grid. In the light of all results obtained, it can be deduced that installation of solar technology for electricity generation proves to be an effective source of add-on to the conventional grid electricity. However, the low degree of social acceptability is due to less awareness among individuals of importance of renewable energy specifically solar power and the associated high initial cost and long cost-payback time compare to other sources of power generation. To overcome these hurdles there is a need for appropriate policy development to usher a more attractive market environment for solar technologies. This is essential for Pakistan to eradicate its energy crisis in a sustainable and environmentally viable manner.

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