ADDING SOLAR POWER FOR NET ENERGY ZERO BUILDING

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Abstract— This paper deals with Building Energy Audit conducted at buildings located in a hilly region of West Bengal state and also provides the prospect of using solar energy to make all buildings achieve the status of Net Energy Zero Building. The study was conducted during the month of November-December 2017. This paper focuses on 13 identified buildings having roof of either flat or shed type which are shadow free and suitable to install roof top solar PV power plant. The total connected load, its type and roof area for each building is computed during the audit process. From the preliminary building energy audit data, the cost saving potential is calculated along with payback duration. As the buildings are in hilly region, we have also most hydro power plants (micro , mini and small) located similar to these regions thereby it can be implemented into all of hydro power stations across India. Solar power can be utilized through building integration or through floating solar PV plants in the reservoir (dam water storage areas) of hydro power stations.

Index Terms— net energy zero building, energy audit, solar pv plant, buildings, hilly region, roof top, hydro power plant

1 INTRODUCTION

The consumption through renewable resources of energy is rapidly increasing in India. Solar energy industry, one of the prospective energy sources, is a fast developing industry in India. The country's solar installed capacity has reached 75 GW in year 2018-19 [1].The energy consumption is rising competitively to meet the demands in the country. The major types of power generating stations in India are thermal, hydro, nuclear and other renewable energy sources (RES) which constitute around 64%, 13%, 2% and 21% respectively of the total electricity generation [1]. This section introduces the location, connected load & solar roof top potential and defines the scope of the Building Energy Audit conducted for office buildings located in a hilly region of West Bengal. As far as the buildings are concerned; it mainly consists of Administration building, hostels, guest houses, Security camp, buildings near power control room and gate operating room. Building energy audit was carried out for various buildings mentioned in Table 1 along with renewable energy (solar roof-top) assessment at the buildings.

Table 1: Type of buildings

Shed type buildings	Roof type buildings
Admin building	Power control room
Field hostel	Power control DG room
Guest house	Gate operation control room
Security camp	DG buildings for gate operation
Store room	Switch yard control room

2 SOLAR ROOFTOP ASSESSMENT

Solar Rooftop System is an arrangement of interconnected components installed on the roof of a building with the purpose of converting sunlight into electricity. The installed Solar Panels absorb and convert solar energy directly into electricity. The DC electric current generated is converted into AC with the inverter of appropriate size. Table 2 shows the summary of office buildings. It is observed that the temperature is gradually increasing from March month to July and gets saturated in August and September months and then slowly decreases. The pattern of relative humidity seems to almost follow air temperature curve during the year except in the month of February and March. Figure 1 shows the variation of daily solar radiation at hilly region of West Bengal with time.

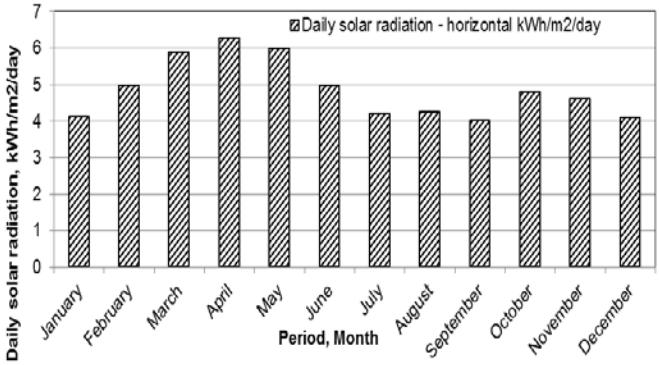

Figure 1: Variation of daily solar radiation(horizontal) with time.

The average daily solar radiation is 4.85 kWh/m2/day at the hilly region of West Bengal. Average solar irradiation in West Bengal state is 1156.39 W / sq. m.

Table 2: Brief summary of office buildings

Sl. No.	Particulars	Description
1.	Latitude	26.927
2.	Longitude	88.455

3.	Sanctioned load/contract	100 kVA
4.	Annual electricity consumption from Mar 2016-Mar 2017	21.8 MWh
5.	Monthly electricity rate	7.12 Rs./kWh
6.	Total roof area available	6270 sq. m
7.	Recommended solar rooftop PV capacity	522 kW

3 EVALUATION OF THE BUILDINGS

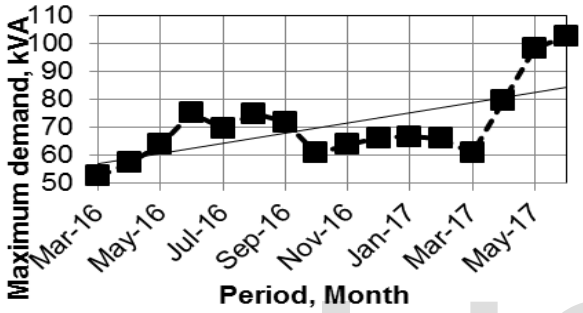

Figure 2: Variation of monthly maximum demand of office buildings.

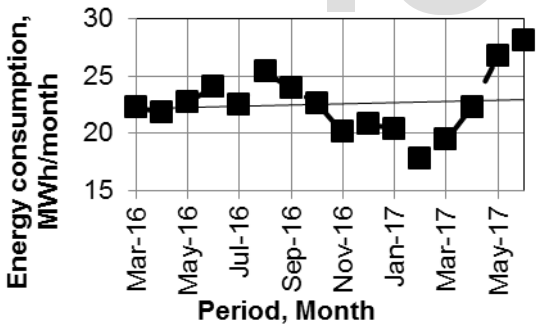

Figure 3: Variation of monthly energy consumption of office buildings.

Figure 2 shows the maximum demand variation and Figure 3 shows the monthly energy consumption which amounts to 361 MWh annually for this location. There are about thirteen individual building identified in the scope of this paper which are provided in Table 3. Power control building has flat roof with strong base for installation for solar roof top but is not recommended for installation of solar PV modules on roof top, as the roof is located very high(from ground) with no parapet (boundary wall is no available). Also this is a disadvantageous position as the regular operation and maintenance will be very difficult at that height. The power control room building is located near gate operating room area which is exposed water droplets & formation of water vapour over the solar PV modules causing the material used for solar roof top to corrode easily. The connected load of electrical appliances is provided in Table 3 & 4. The total connected load of electrical appliances like fans, AC's, fridge, room heaters, geysers, induction stoves and tea pots is observed to be 155.31 kW. The total connected load of electronic appliances used is provided in Table 5. The total connected load of electronics appliances like computers, printers, photocopiers and TV's is 25.23 kW. The connected load of lighting appliances is provided in Table 6. The total connected load of lighting appliances like TFL tubelights, LED lights, CFL lights and GSL lamps is 16.27 kW.

Table 3.1: Connected load of electrical appliances

Sl. No.	Location	Fan			AC					Total
		Ceiling Fan	Exhaust Fan	Table Fan	991 W	1467 W	1802 W	1571 W	2000 W	
1.	Admin Building	53	12	23	2	23	5	2		
2.	P & C Office	6	12	12	6					
3.	Executive Field Hostel (OLD)	15	6	1					11	
4.	Mech / Electronic room or Substation	6		7						
5.	Executive Field Hostel(New)	34	16							
6.	Hospital	5	1	2					2	
7.	Canteen	4	1	2						
8.	Non- Executive Field Hostel	14								
9.	Driver Room	4								
10.	COY Office / SECURITY Office	1		1			1			
11.	DG/ Generator room	1								
12.	Store Room/ Wash Room	2								
13.	Driver Resting Room	1								
14.	**Total Samples**	146	48	48	8	23	6	2	13	
15.	**Wattage per sample**	70	60	55	991	1467	1802	1571	2000	
16.	**Total kW**	10.22	2.88	2.64	7.93	33.7	10.8	3.14	26	97.31

Table 3.2: Connected load of electrical appliances

Sl No	Location	Fridge	Heating equipment's				Total
			Room Heater	Geyser	Induction Stove	Tea Pot	
1	Admin Building					5	
2	P & C Office						
3	Executive Field Hostel (OLD)	5	2	10			
4	Mech / Electronic room or Substation						
5	Executive Field Hostel(New)	1		12			
6	Hospital	1					
7	Canteen	1					
8	Non- Executive Field Hostel		2	2	2		
9	Driver Room						
10	COY Office / SECURITY Office						
11	DG/ Generator room						
12	Store Room/ Wash Room						
13	Driver Resting Room						
14	**Total Samples**	8	4	24	2	5	
15	**Wattage per sample**	1000	1000	1500	2000	1200	
16	**Total kW**	8	4	36	4	6	58

Table 3.3: Connected load of electronic appliances

Sl No	Location	Electronics					Total
		Computer	Printer	Xerox	TV	Power Socket 15A	
1	Admin Building	54	36	6			
2	P & C Office	14	6	1		14	
3	Executive Field Hostel (OLD)	3	2		11	50	
4	Mech / Electronic room or Substation	8	5	1			
5	Executive Field Hostel(New)	1	1		12	52	
6	Hospital	3	3			8	
7	Canteen				1	6	
8	Non-Executive Field Hostel				10	59	
9	Driver Room				1		
10	COY Office / SECURITY Office	2	2				
11	DG/ Generator room					1	

Table 3.4: Connected load of lighting appliances

Sl No	Location	Tubelights			LED		CFL	GSL Lamp	Total
		72W	40W	36W	20W	9W			
1	Admin Building	23		132		2	3		
2	P & C Office			24					
3	Executive Field Hostel (OLD)			62		11	5		
4	Mech / Electronic room or Substation			12					
5	Executive Field Hostel(New)			52		12	11		
6	Hospital			11					
7	Canteen						13		
8	Non-Executive Field Hostel			56		3	4		
9	Driver Room			4	1		5	5	
10	COY Office / SECURITY Office			3		2			
11	DG/ Generator room			3					
12	Store Room/ Wash Room		3						
13	Driver Resting Room		1						
14	**Total Samples**	23	4	359	1	30	41	5	
15	**Wattage per sample**	72	40	36	20	9	18	100	
16	**Total kW**	1.66	0.16	12.92	0.02	0.27	0.74	0.5	16.27

The individual buildings (shadow free) were studied and the following observations were found:-

i. Three roofs (all inclined) are available above the administration building for installation of solar rooftop system. All the roofs are inclined in nature each with parallelogram, trapezoidal and triangular shapes.

ii. One north-south faced flat roof (iron rods extending over the roofs) is available for installation of solar rooftop system above the P&C office.

iii. Two roofs are available for installation of solar rooftop system above the executive field hostel (old).

iv. Flat roof is available for mechanical/electrical room/ substation.

v. North- south facing roofs are available above the hospital, canteen, Security/COY office [flat rooftop with strong foundation] and DG room.

vi. South-north facing rooftops are available at non-executive field hostel and driver room (titled rooftop).

vii. Two roofs are available above store/ wash room and one roof available at driver resting room behind the administration building.

The parameters like area of roof available, height of the building from bottom, solar potential are provided in Table 7. The total available area is 6270 sq. m on the roof to install the SPV power plant. As per industry practice the area required per kWp is around 12 sq.m/ kWp. So a total of 522 kWp plant can be installed at the roof tops available at buildings. The cost savings for implementing LED with existing TFL and CFL light fixtures is shown in Table 8. For street lights, the replacement of LED fixtures in place of tube lights of different wattages, CFL and halogen lamps will lead to annual savings of Rs. 3.2 Lakhs with payback period of 17 months.

Table 4: Solar roof top availablility at buildings

Sl No	Location	Length (m)	Width (m)	Elevation (m)	Area (sq. m)	Solar Potential (kW)
1	Admin Building					
1.a	Roof Section 1	13.9	9.1	6.0	126.5	11
1.b	Roof Section 2	55.4	13.9	6.0	770.1	64
1.c	Roof Section 3	13.9	9.1	6.0	126.5	11
2	P & C Office	16.2	10.5	5.2	170.1	14
3	Executive Field Hostel (OLD)	67.4	10.7	6.4	721.2	60
4	Mech / Electronic room or Substation	8.7	8.7	7.9	75.7	6
5	Executive Field Hostel(New)	28.0	12.4	10.5	347.2	29
6	Hospital	16.5	12.6	4.2	207.9	17
7	Canteen	12.4	8.9	5.5	110.4	9
8	Non-Executive Field Hostel					
8.a	Left side	29.8	5.0	5.8	149.0	12
8.b	Front side	35.8	4.7	5.8	168.3	14
8.c	Right side	14.5	3.8	5.8	55.1	5
9	Driver Room	15.6	8.3	4.7	129.5	11
10	COY Office / SECURITY Office	12.9	9.0	5.6	116.1	10
11	DG/ Generator room	16.3	12.8	8.6	208.6	17
12	Store Room/ Wash Room					
12.a	Store Room	11.4	2.6	3.6	29.6	2
12.b	Wash Room	3.2	2.5	3.6	8.0	1
13	Driver Resting Room	8.2	3.1	5.5	25.4	2
14	SECURITY Camp					
14.a	Roof Section 1	4.2	16.1	4.8	67.6	6
14.b	Roof Section 2	16.1	6.0	5.6	96.6	8
14.c	Roof Section 3	43.2	14.4	6.6	622.1	52
14.d	Roof Section 4	9.6	4.9	4.0	47.0	4
14.e	Roof Section 5	38.5	4.7	7.5	181.0	15
15	SECURITY Camp (Office & Recreational hall)	28.8	4.8	5.2	138.2	12
16	Switchyard Control room					
16.a	Roof Section 1	7.8	5.5	5.0	42.6	4
16.b	Roof Section 2	20.5	9.2	5.0	188.2	16
17	Switch yard SECURITY temporary room	11.1	4.5	5.7	50.0	4
18	Switch yard Store room	40.1	15.4	10.0	617.7	51
19	Power control DG Room	20.6	19.0	8.7	389.4	32
20	Gate operation DG Room	9.9	4.6	5.5	45.0	4
21	Gate operation Control Room	12.2	5.8	4.0	70.5	6
22	Intake Power Pack Room (6 Nos. each)	6.4	4.4	3.9	169.0	14

4 Cost analysis of solar roof top PV system for the building's

i. Feasible Plant size as per the building capacity: 522 kW
ii. Cost of the Plant per kW: Rs. 60/ W
iii. Total cost of the plant: Rs. 313.20 Lakhs
iv. Total Electricity Generation from Solar Plant
a. Annual : 700 MWh
b. Lifetime (25 years): 17.5 GWh
v. Financial savings: Tariff @ Rs.7.12/ kWh (for top slab of traffic) - No increase assumed over 25 years:
a. Monthly: Rs. 4.3 Lakhs
b. Annual: Rs. 49.8 Lakhs
c. Lifetime (25 years) : Rs. 1246 Lakhs
vi. Environmental savings
Carbon dioxide mitigated : 14350 tonnes

The total consumption comes to 361 MWh annually but the capacity is 700 MWh which is 93.9% higher than the actual consumption. The solar energy generates during the day where maximum load occurs the night load consumption is comparatively very less .The solar roof top PV power plants on the buildings have to both provide energy to the connected loads considering maximum power drawn during the day and the remaining shall be delivered to the grid (for earning through Net metering) . The energy consumed during the night load shall be taken from grid which will be very less compared to the energy consumed during the day. Hence, the concept of Net Zero building offsetting the energy consumption to the energy delivered to the grid through clean energy.

Table 5: Cost savings by LED implementation

Sl. No	Present fittings (wattage)	Recommended fitting (wattage)	Savings (W)	Operating hours (h)	No. of lamps	Total Savings, kWh/ year	Cost for the Fittings	Annual Saving in cost @ Rs. 7.12	Simple payback, months
1	Tube lights /36 W	LED LAMPS/20W	16	3600	764	44006.4	382000	313325.6	15
2	Tube lights /40 W	LED LAMPS/20W	20	3600	4	288	2000	2050.6	12
3	CFL/18 W	LED LAMPS/9W	9	3600	41	1328.4	20500	9458.2	26

5 Conclusion

The study concludes that the identified 13 numbers of buildings at a hilly region of West Bengal are either with roofs of flat type or shed type and are suitable for installation of Solar roof top power plants. A total of 522 kWp can be installed at the rooftop available on buildings covered under the scope. LED lights are recommended to be used wherever TFL & CFL are used. For a daily average of 5 hours sunlight duration & 270 working days p.a. and with estimated solar potential of 522 kW, the annual generation from PV comes to 700 MWh. Total cost of the plant for 522 kWp roof top solar PV power plant is Rs 313.20 Lakh. With the tariff rate of Rs 7.12 / kWh (with assumption of no increase for 25 years), the financial savings will be Rs 49.84 Lakhs (annually) and the payback period will be around 6 – 7 years. The net zero building is achieved by having almost twice the total connected load of the office buildings. The energy consumed is equal to and less than the energy generated through clean energy along with the implementation of LED for lighting system so that the buildings are energy efficient. Also as the buildings analyzed were considered in hilly region for this paper, we have also the maximum number of t hydro power plants (micro , mini and small) located similar to these regions thereby it can be implemented into hydro power stations of India. Solar power can be utilized through building integration or through floating solar PV plants in the reservoir (dam water storage areas) of hydro power stations.

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