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ANALYSIS OF GRID TIED SOLAR ROOFTOP SYSTEM: A CASE STUDY ON STARS HOMES, SITAPAILA, NEPAL

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Abstract

Most of the nation demand is from the residential sector. Thus, the objective of this paper is to supply the required energy from the same demand point from the solar PV installed in the residential sector that is technically feasible for the given sector. The survey is conveyed on Star Homes(Residential Sector) situated at Sitapaila, Kathmandu. The total potential for installation of PV on useable areas of the rooftop of Stars Homes is calculated to be 253.2 kWp. For the comparative analysis in this paper, the isolated PV system is designed/ analysed using PV-SYST and the grid tied PV including/excluding battery is designed/analysed using SAM(System Advisory Model) software for one of the Type 1 home with annual demand of 2208 kWh. In grid interactive PV system with battery, the peak shaving and backup power during outage is facilitated and also the excess energy is supplied to the grid as well.Theenergy generated from the designed system for type I system with 3.9 kWp grid tied system is 6483 kWh and with 3.9 kWp grid interactive system with battery size of 5.2kWh Lithium Ion is 6454 kWh annually. Similarly, energy generated from designed system of standalone with 1.62 kWp PV and battery size26V, 322Ah system is 3066.6 kWhannually out of which 795kWh is lost annually due to full battery charged conditions. The LCOE considering 25 years life time with 7.5 % loan interest for 15 years for type I with standalone system is 21 cents/kWh, grid tied PV system is 4.94 cents/kWh and with grid tied PV battery system is 6.73 cents/kWh. The peak shaving obtained from the grid tied with battery system compared to the grid tied system is 0.8 kW. The net saving on electricity bill for grid tied system is 516$ and for grid tied system with battery is 526$ annually considering net metering.

Keywords: *Residential Sector – Solar Rooftop – Grid Tie – Battery*

1. Background

Nepal is aiming to achieve high economic growth through its fifteenth national plan and become highly developed countries within 2100B.S. However, one of the key constraints of Nepal's development is energy security. Although Nepal is rich in hydropower resources, Nepal is unable to realize enough hydropower generation and fulfill the electricity demand internally. Moreover, Nepal has been declared load shedding free zone only after its door opened for massive import of electricity from the neighboring country, India. Nepal imported more than one third of electricity(42.3%) from India last year(NEA, 2018-19). This has shown the status of Nepal as strivingfor energy and lagging in self independency in the field of energy.

Thus, solar PV systems could be potentially an attractive alternative for the energy hungry residential sector converting each house as a power source. Recently, doors have been open up by the National Planning Commission via sustainable development goals(SDG 7) which targetsto have access to electricity by 99% by introducing energy mix concept. The SDG has targeted to increase the share of the renewable energy upto 50% by 2030A.D.At present, in major cities of Nepal such as the Kathmandu Valley, rooftop solar PV's have not been broadly installed yet either by households or by commercial and industrial users due to non user friendly policy and unattractive subsidies from the government. Recently, the guidelines has been formulated by the Ministry of Energy for the net-metering of grid tied PV systems which allows owner of PV system to sell the excess energy generated to grid through net metering (MOE, 2017/18). This paper has focused to perform techno-financial analysis of the rooftop solar considering the net metering.

2. Methodology

The data required for the research work is collected at different levels. Climatic conditions, meteorological data, market conditions, national electricity grid conditions, national electricity tariff rates, available subsidy policy, domestic/residential user's survey data is obtained from relevant places. A survey on group of residential users of star homes (middle-upper class families) has been carried out in order to focus on category of potential users of PV grid connected system with battery backup through interview with the questionnaires prepared for the survey

The design for three cases i.e with Standalone system, Grid connected PV system and Grid interactive PV system with backupisdone.For all three cases, financial analysis is carried out considering net metering.

3. Data Analysis

The load profile data is graphed for all surveyed households. From the demand load data stored in TOD meter, the reliability (grid outage) of local distribution grid is also analyzed.

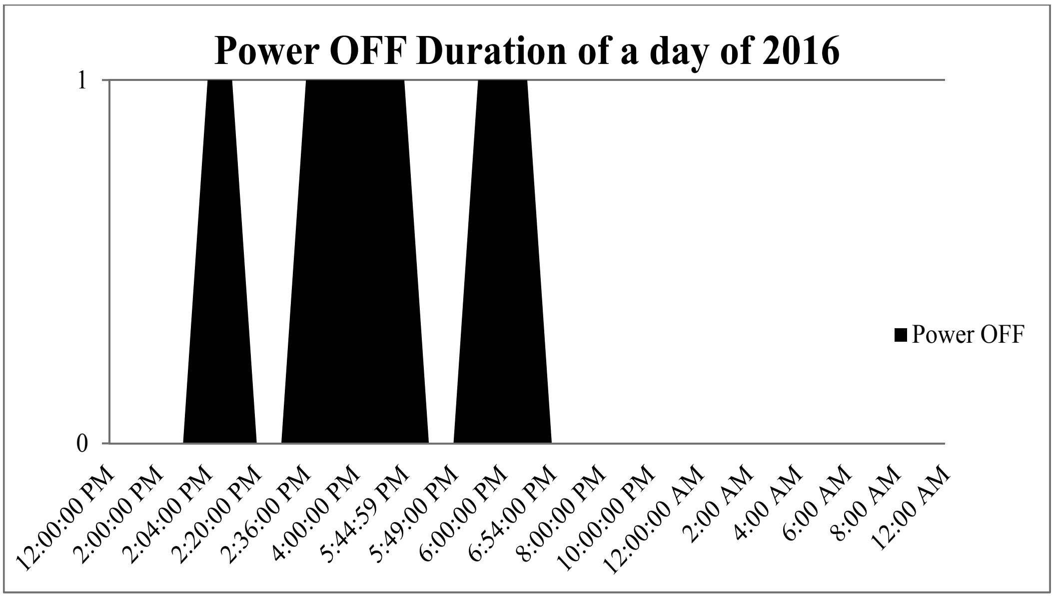

Fig 1: Outage of a certain day of the feeder feeding Stars Homes

S. N	Type/No	Size	Rooftop Area(m^2)	Lad (VA)	Area including all rooftop	Usable area for Solar installation	PV Potential(kWp) 300Wp @1.44 m2	Total potentialkWp
1	Type I: 4	Small	<= 60	<2000	52.3 m^2	19 m^2	3.9 kWp	4*3.9=15.6
2	Type II:43	Medium	60-150	2000-4500	123 m^2	24 m^2	4.8 kWp	43*4.8=206.4
3	Type III:4	Big	>=150	>4500	165 m^2	38 m^2	7.8 kWp	4*7.8=31.2

Manual dimension measurement is carried out in order to calculate the usable rooftop area and the solar potential of rooftop area of each type of house. The houses of Stars homes are categorized according to the rooftop area and load as shown in the table.

Table 1: House type categorization and rooftop potential

4. Energy Consumption Pattern

The energy consumption pattern of the houses that were surveyed are presented in the bar chart shown below:

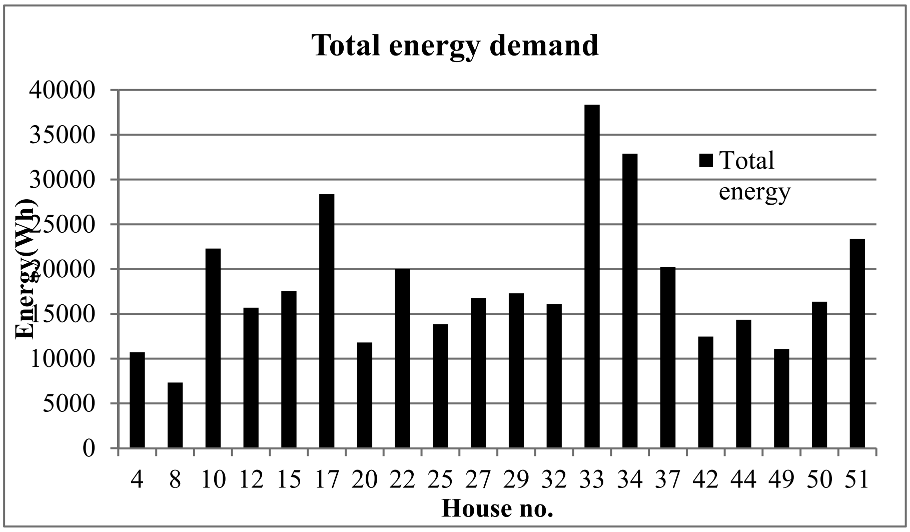

Fig 2: Bar chart of the Total Energy Consumption of Individual house in Weekend

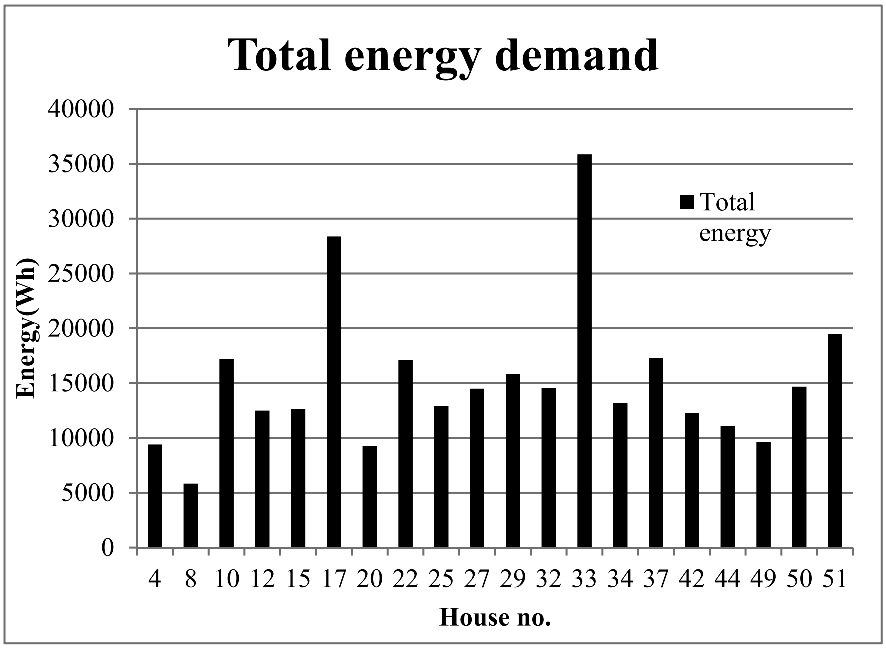

Fig 3: Bar chart of the Daily Energy Consumption of Individual house in Weekdays

6. Results

Table 2:Design Summary of the Type 1 house

Particular	**Standalone PV Design for Type 1**	**Grid Tied PV Design for Type 1**	**Grid Interactive PV System with Battery backup for Type 1**
Installed Capacity/Potential	1.62 kWp	3.9 kWp	3.9 kWp
Solar Panel	6 modules of 270 Wp of Canadian Solar CS6P-270PMix	13 modules of 300Wp of Canadian Solar CS1K300-MS	13 modules of 300Wp of Canadian Solar CS1K300-MS
Inverter	2 kVA Luminous	2.962 kWSolarEdgeSE3000H-US	3.68 kWSolarEdgeSE3680H-RWSACBNN4
Battery	LFP-CB 26V 322 Ah	No battery	5.2 kWh Tesla Lithium Ion Battery

The stand alone system is designed and simulation is performed using PVsyst. The simulation results for the stand alonePV system is as shown below.

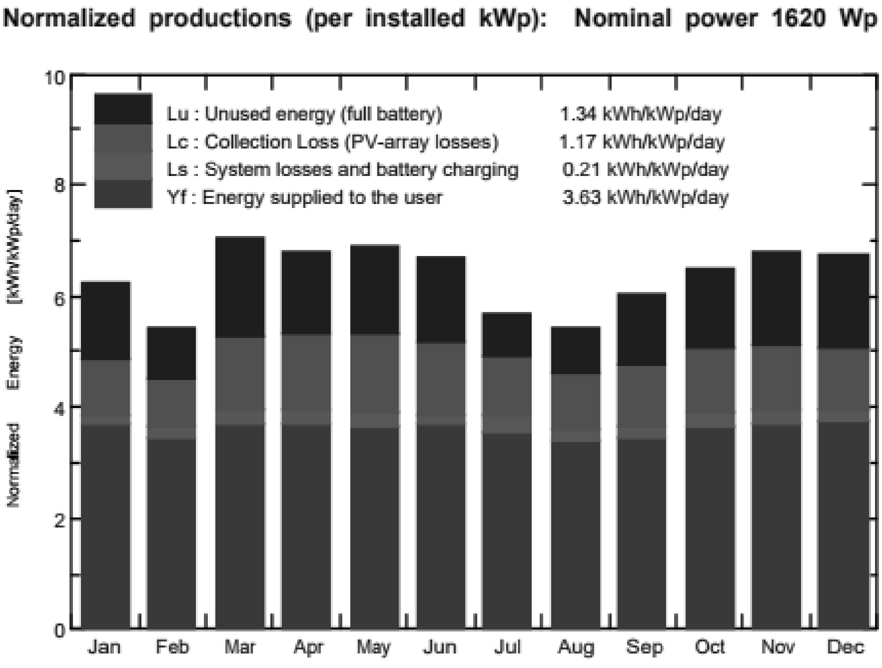

Fig 4: Energy production from the system from the standalone designed for Type I

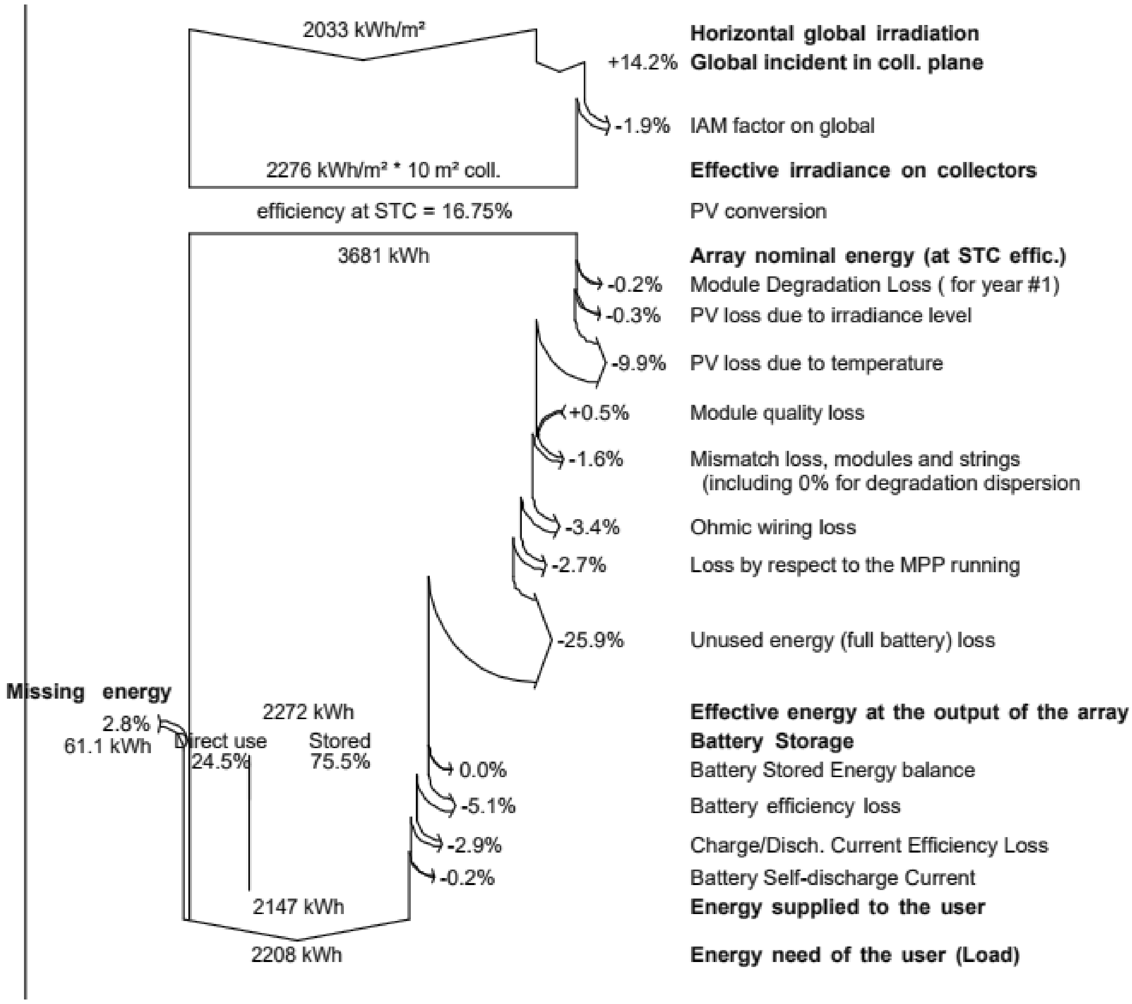

Fig5: Loss Diagram Over year

The above designed system has 2.8% missing energy and 25.9 % energy lost due to some situations at which battery is fully charged and solar panel is generating excess energy than required by the load.

Another type of the design i.e. grid tied PV is designed using SAM. The simulation results for grid tied PV is as shown below.

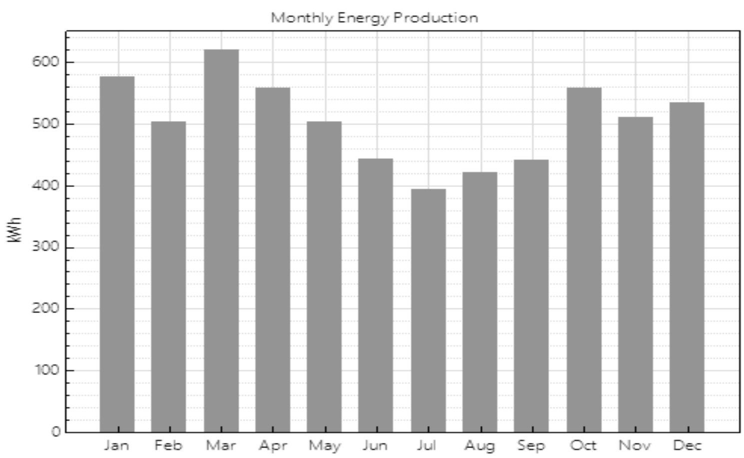

Fig 6: Generation from Grid Tied PV for Type I

The graph shows the total AC energy supplied from PV, the electrical load and the surplus energy is cumulated every month and shown at the end of the year.

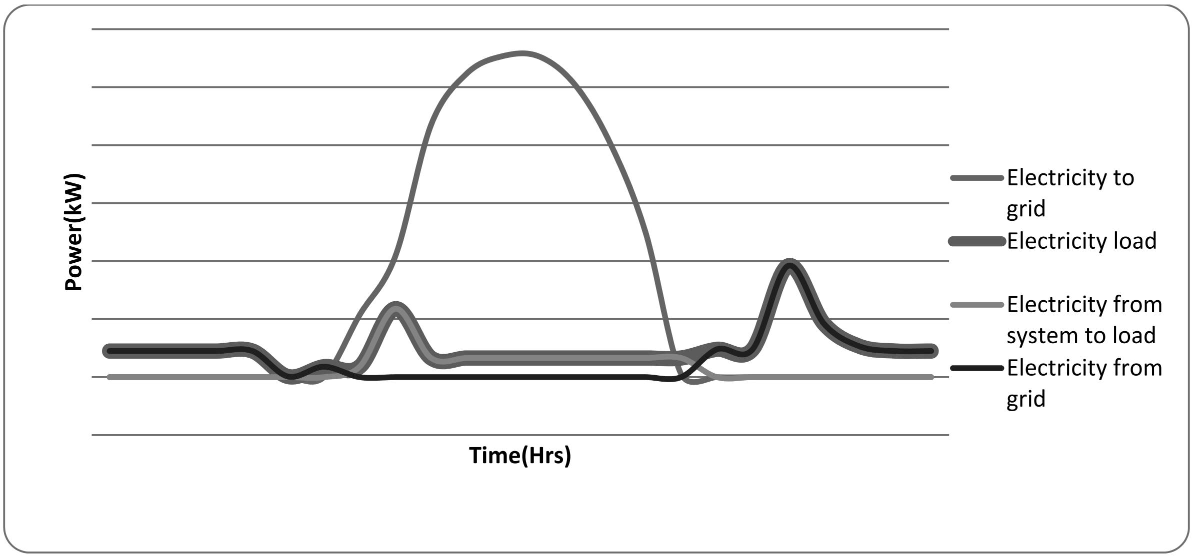

Fig 7: Electricity from PV to load, PV to grid, grid to load for Weekdays for Type I

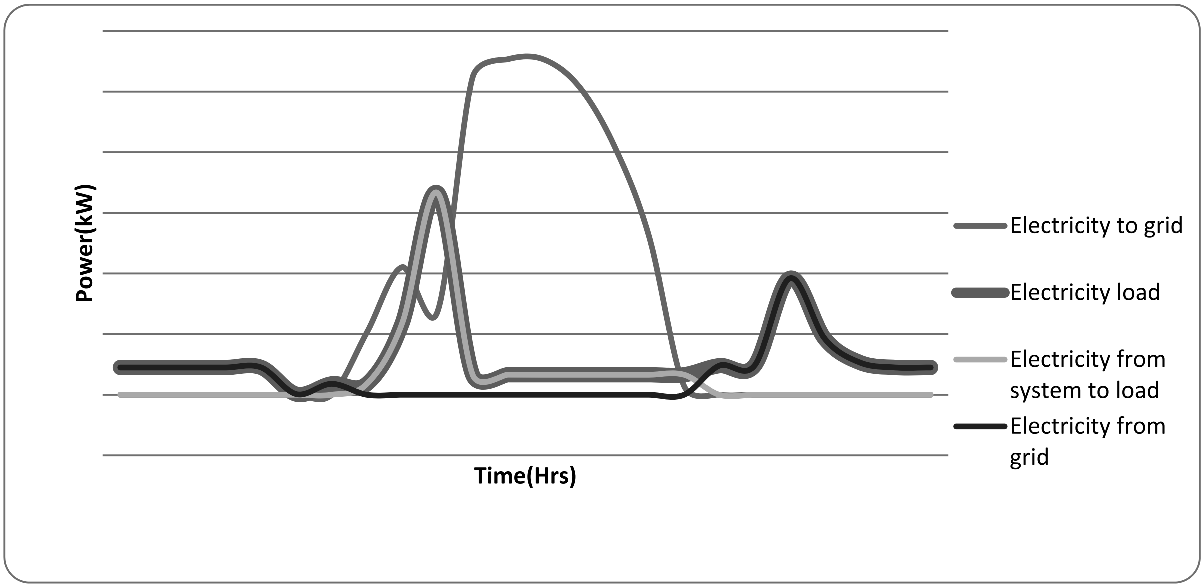

Fig 8: Electricity from PV to load, PV to grid, grid to load for Weekend for Type I

The grid tied PV with battery backup is designed using SAM. The simulation results for grid tied PV with battery backup is as shown below.

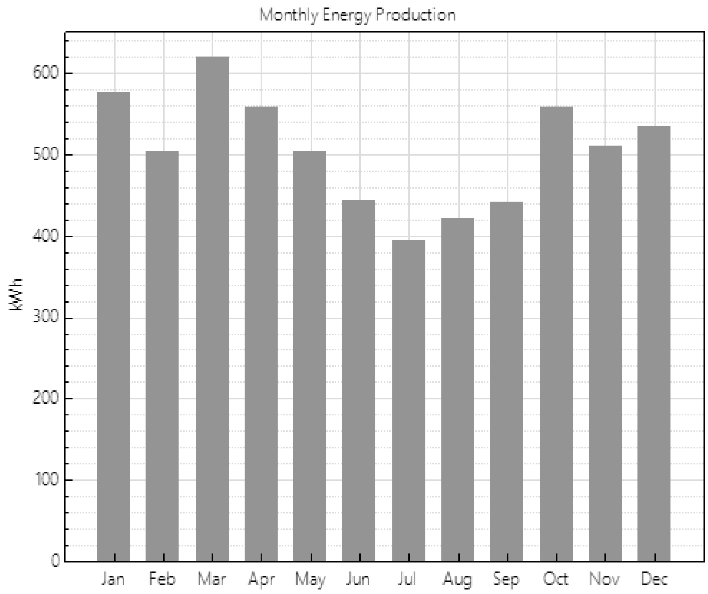

Fig 9: Generation from PV for Grid Tied with battery backup for Type I

The graph shows the total ac energy supplied from PV, the electrical load and the surplus energy is cumulated every month and shown at the end of the year.

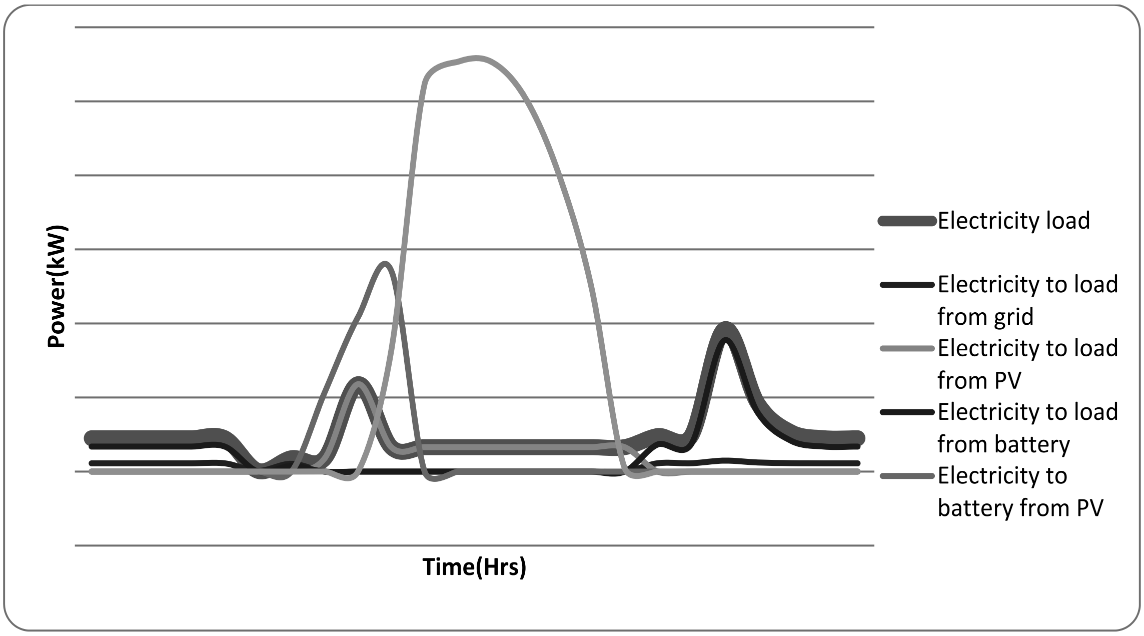

Fig 10: Electricity from PV to load and battery, PV and battery to grid, grid to load for Weekdays for Type I

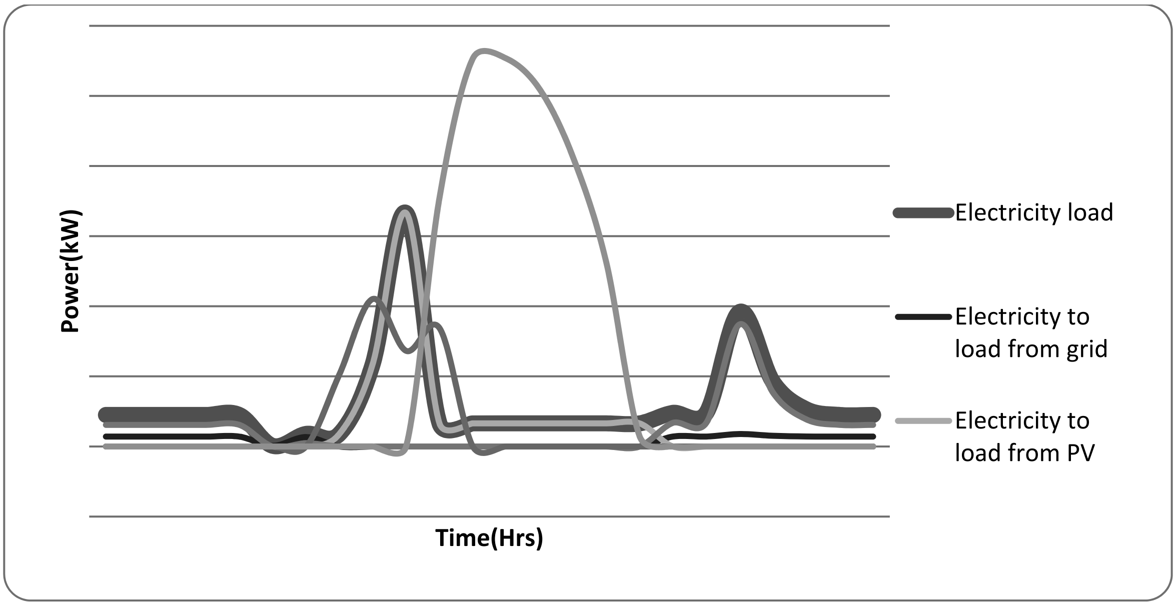

Fig 11: Electricity from PV to load and battery, PV and battery to grid, grid to load for Weekend for Type I

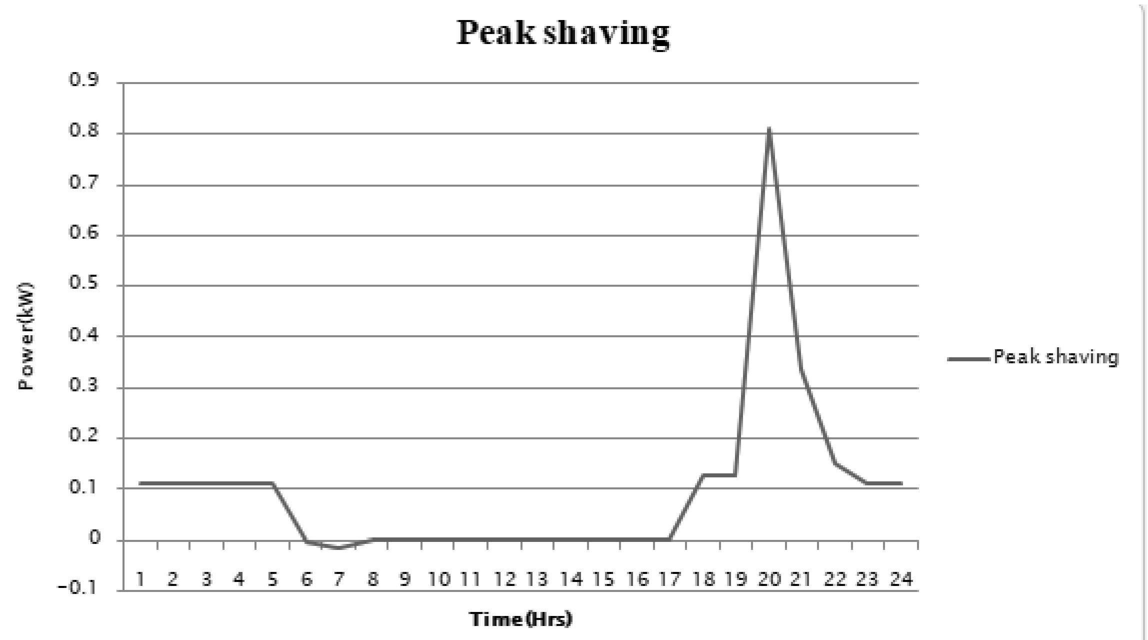

Fig 12: Peak shaving achieved in Grid Interactive PV with Battery Backup

Table 3: Result Summary for the Type 1 House

S.N	Financial Summary	Software used for simulation	Result (yearly)
Standalone system	Gross Investment 2695 USD @ loan rate of 7.5% Energy Cost: 0.21 USD/kWh Specific cost: 1.66 USD/Wp	PVSYST	Load=2208 kWh Energy available=3067 kWh Excess Energy= 795 kWh/year Energy=1893 kWh/kWp Performance ratio: 0.5709 Solar fraction=0.9723
Grid tied PV system	Gross Investment 4312 USD @ loan rate of 7.5% Energy Cost: 0.066 USD/kWh Specific cost: 1.1USD/Wp	SAM	Load=2208 kWh Energy PV=6066 kWh Energy export=5228 kWh Energy import=1369 kWh Performance ratio=0.82 Energy=1683 kWh/kWp
Grid interactive system with backup	Gross Investment 5182 USD @ loan rate of 7.5% Energy Cost: 0.08USD/kWh Specific cost: 1.3 USD/Wp	SAM(peak shaving dispatch model to aid INPS grid)	Load=2208 kWh Energy PV =6003 kWh Energy export=4320 kWh Energy import=524kWh Performance ratio=0.81 Energy=1665kWh/kWp Battery charged from

7. Sensitivity Analysis

For the billing analysis, three scenarios is considered. The first scenarios is the block tariff structure which the tariff structure applied to the residential sector by NEA. The nest scenario is the Time of Day tariff structure. Since this type of tariff structure is not applicable in the residential sector, so the tariff structure of the commercial sector for the 11 kV consumer is applied. And the other scenario is the average rate of the block rate tariff structure applied to the residential sector.

The sensitivity analysis on the Grid tied PV system is as follows:

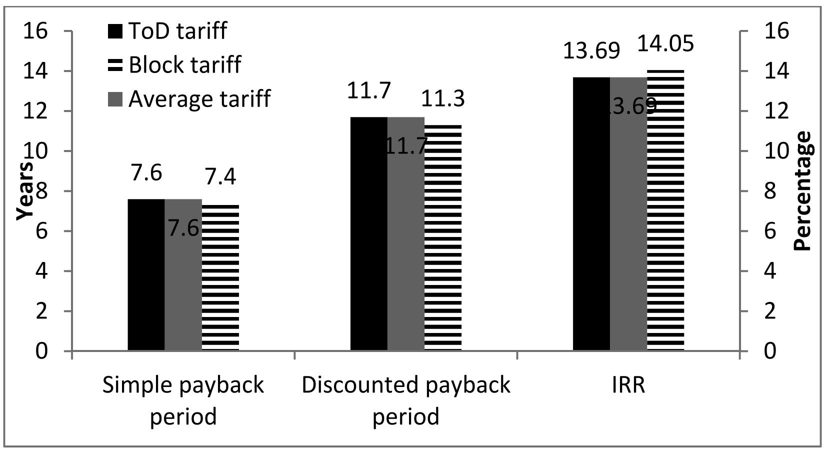

Fig 13: Sensitivity analysis for payback period and IRR for Grid Tied System

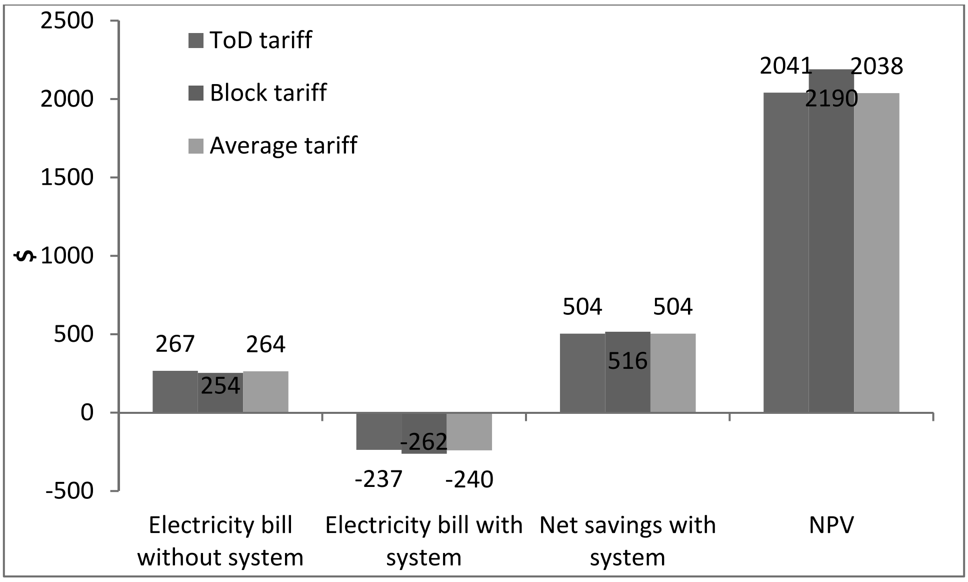

Fig 14: Sensitivity analysis for the different tariff structure in Grid tied system

The sensitivity analysis on the Grid tied PV system with battery is as follows:

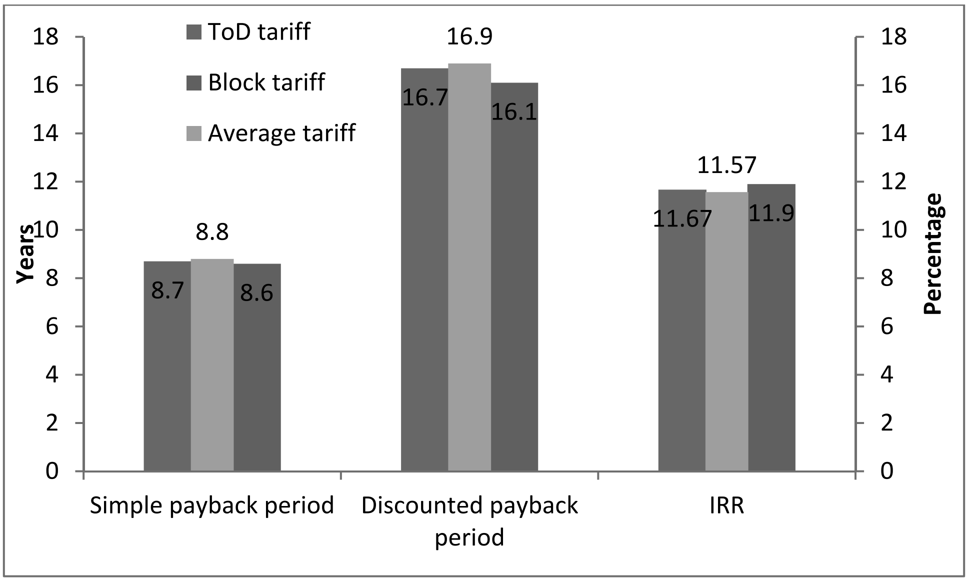

Fig 15: Sensitivity analysis for payback period and IRR for Grid Tied with Battery backup

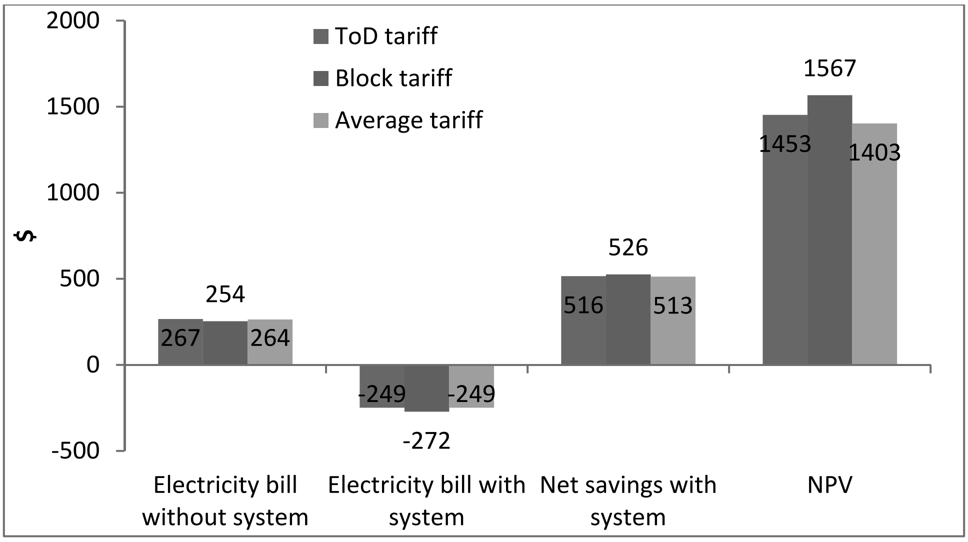

Fig 16: Scenario analysis for the different tariff structure in Grid tied system with Battery

8. Comparative Analysis

The comparative analysis for the system with and without battery is tabulated below

Table 4: Comparative analysis of the grid tied system with and without battery

S.N.	Parameters	Grid Tied System	Grid Tied System with Battery
1	Annual energy(kWh)	6483	6459
2	Capacity factor(%)	19	18.9
3	Energy yield(kWh/kW)	1660	1654
4	Performance ratio	0.8	0.8
5	Battery efficiency li ion(%)		91.78
6	Nominal LCOE(cents/kWh)	7.03	8.37
7	Real LCOE(cents/kWh)	4.94	5.88
8	Electricity bill without system($)	254	254
9	Electricity bill with system($)	-262	-272
10	Net savings with system($)	516	526
11	NPV($)	2190	1567
12	Simple payback period(years)	7.4	8.6
13	Discounted payback period(years)	11.3	16.1
14	Net capital cost($)	4311.95	5182.09
15	Cost per capacity($/Wdc)	1.1	1.33
16	IRR(%)	14.05	11.9

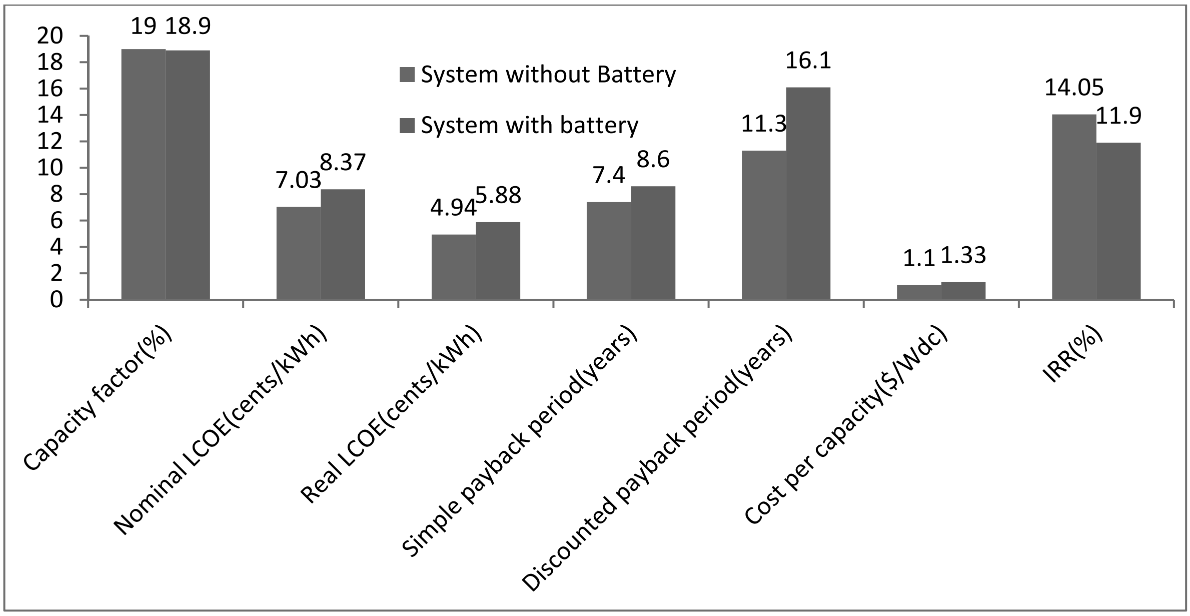

Fig 17: Comparison of Grid Tied System with and without battery

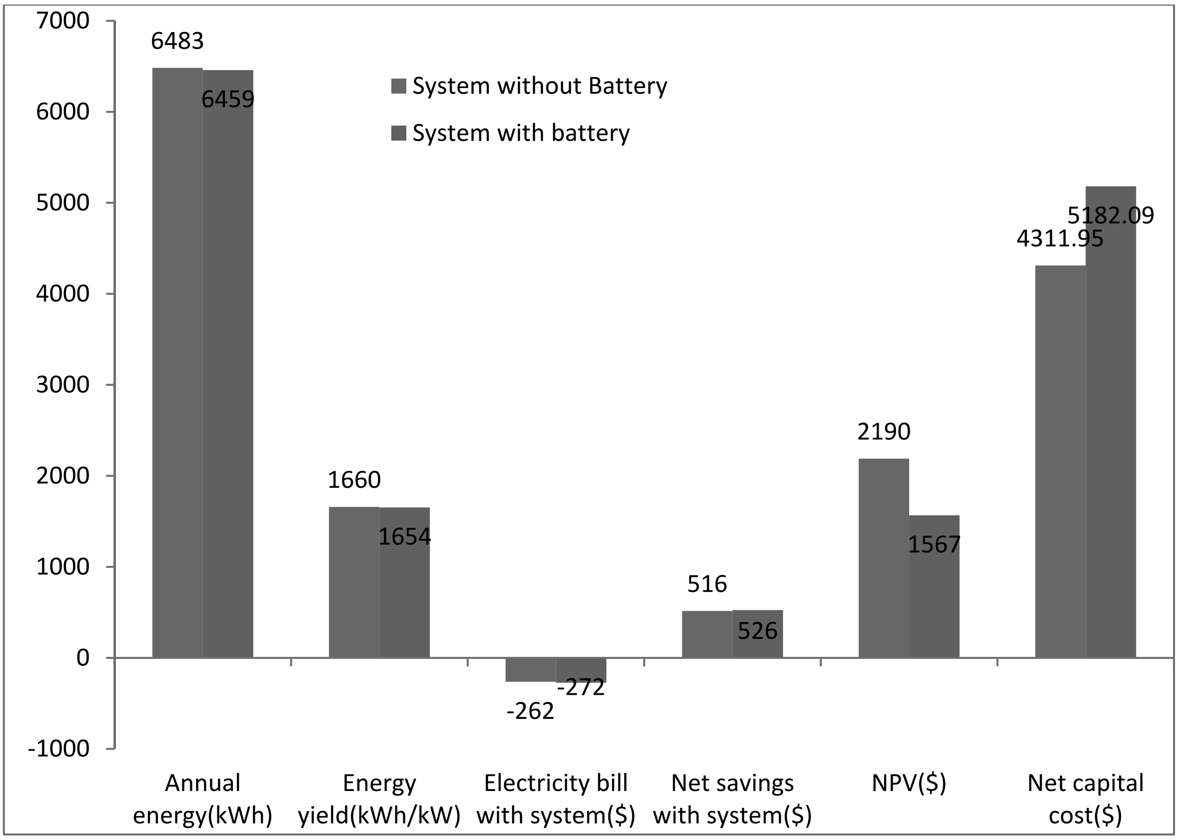

Fig 18: Comparison of Grid Tied System with Battery and without Battery

9. Conclusions

According to the house type and the survey performed, type 1 house has maximum load of 1665 W with energy demand of 2208 kWh yearly, type 2 house has maximum load of 2350 W with energy demand of 4487 kWh yearly and type 3 house has maximum load of 4175 W with energy demand of 8167 kWh. The total potential for installation of PV on useable areas of the rooftop of Stars Homes is calculated to be 253.2 kWp. This paper analyses the three types of design on type 1 house i.e. standalone PV system, grid tied PV system and grid interactive system with battery backup.In standalone system, PVSYST simulation results show the designed system of 1620 Wpis capable to match the load for type 1 of the building and thus, it is independent from the grid but the excess generated energy is being wasted during the situation of fully charged battery condition and minimal demand of load than generation. Energy generated from the designed system of 3.9 kWpfor type I system with grid tied system is 6483 kWh and with grid tied battery system is 6454 kWh. The LCOE considering 25 years life time with 7.5 % loan interest for 15 years for type I with grid tied system is 4.94 cents/kWh and with grid tied battery system is 5.88 cents/kWh.This system aids the grid than the traditional inverter battery backup system which takes grid power to store the energy in the battery.

Similarly, the peak shaving obtained from the grid tied with battery system compared to the grid tied system is 0.8 kW. The net saving on electricity bill for grid tied system is 516 $ and for grid tied system with battery 526 $.

10. Assumptions/ Limitation

a) The surveyed load profile is assumed similar for similar type of houses. Thus, its average is used for the design. However, data logger in each house would only give exact real load profile data for accurate design. The load profile of similar house type is averaged assuming they have similar daily requirement.

b) Many hesitated to answer the questions. Many were unaware of technical terms. Thus, the reliability of surveyed data cannot be assured.

c) As the Nepal market is still unaware of the grid connected inverters accessories, lithium ion batteries, their cost shall be assumed from the international market without considering custom and transportation charges.

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