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Study on Grid Integrated Solar PV for Balaju Industrial District, Kathmandu, Nepal

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Abstract
The research works aims to study the Grid Integrated Solar PV for Balaju Industrial District, Kathmandu, Nepal. The total electrical energy consumption in Balaju Industrial Estate was found to be around 19,994 MWh and diesel fuel consumption was found to be around 13,746 MWh(based on equivalent calorific value) in 2016 from field survey. Based on load consumption, roof area, solar insolation and photovoltaic system efficiency and Nepal Electricity Authority's selling and buying tariff rate, the average size of photovoltaic module, converter, photovoltaic-maximum power point tracker, was calculated to be 1,537.94 kW, 1,922.42 kW and 2,114.66 kW respectively using HOMER Pro Simulator. For the financial analysis, Total Net Present Cost and Average Levelized Cost of Energy (LCOE) were calculated to be around NRs. 1,886.41 Million and NRs. 9.61 per kW for an initial investment of NRs. 2,183.63 Million and Discount rate of 14% using HOMER Pro Simulator. The LCOE per kW of Food Product sector, Chemical rubber and plastic sector, other manufacturing, wooden product, Electrical Engineering product and mechanical engineering product was calculated to be NRs. 11.48, 4.69, 10.58, 6.89, 12.01and 12 respectively. It was found that the total emissions reduction after replacing diesel with solar PV system was calculated to be 3,294.37 tons CO2 equivalent in 2016.

Keywords
Solar PV system – Energy System – Diesel Fuel Energy – Electrical Energy

1. Introduction

Balaju Industrial District (BID) is a pioneer industrial district which established in 1960 AD; financed by Nepal Government and USAID. BID has a total area of 670 ropanies out of which 540 ropanies are well developed. The land occupied by service sector is 130 ropanies. Currently there are 131 industries established inside the district out of which 97 industries are in operation. The power capacity is 6MW [1].

Nepalese industries are forced to relay on diesel generators and inverters for constant electricity.Further, system cost for diesel generators or inverters are around Rs. 40 per unit cost [2]. It is oviously that Energy accounts play a significant share of manufacturing cost. Further, DG sets supplied 28% of electriciy in Kathmandu valley in 2012/2013; Which produced as much as 220 tons of Black Carbon in environment[3].

Study shows 64% of fuel (18915410 GJ) on 7.89% (=29700000 GJ) of total energy (=376300000 GJ); is consumed by Process heating of industry in Nepal.Further, Majority of this energy is supplied from the Coal, fuel wood, diesel and electricity with 48.24%, 23.83% , 15% , and 13.61% [4]. With the consequent increase in the black carbon production and that cost of diesel used as a fuel for backup power, businesses are looking for alternative and more sustainable sources for power production. Whereas, study shows feasible and viable with LCOE is 14.94 /kWh and 11.40/ kWh for on-site and off-site power plant respectively with 10% discount rate [5].

According to NEA report, the number of complete system collapse has been reduced to 26 as compared to 28 in previous year and subsequent complete outage time has been reduced to 430 minutes as compared to 1053 minutes (465 minutes during the earth quake) in the previous year. Maximum load shedding duration is 91 hr/week in 2015 [6]. Provisional figure for Peak load

interconnected system is about 1385.30 GWh in 2016 which is 7.3% increased value previous year and provisional total available electric energy 5005.7 GWh in 2015 and will increased by 1.89% in 2016.

Solar Power Plant will prove to be a viable source for reducing the current gap between demand and supply of electricity in industry [7].which also concluded the positive indications on having a new source in Neplease electrictiy mix in very near future. It is well known that Nepal has abundant sunlight that could support robust solar-based power production to resolve the environmental, economic and energy issue. Thus, solar photovoltaic (PV) and solar thermal based power production may thus be an effective alternative in Nepal[8].

The interest in substituting diesel with solar has been spurred by:

- Burgeoning power deficit: 1026.65MW of Peak demand in 2012 and 1291.10 MW in 2015 - about 25% increase in 4-years period in Nepal[6].
- Rapid escalation in demand of diesel fuel consumption in Nepal (about 10-12% yearly) [9].
- Steep decline in cost of solar power (40% reduction in module prices in 2011-2012).
- Favorable policies encouraging the use of solar power (capital subsidies, soft loans etc.) and encouraging to connect the Net Metering System in Nepal[10].

2. Material and Methods

According to Industrial District Management, there are altogether 131 industries in BID. Based on category and sub-category, 54 sample sizes are determined[11]. These industries are categorized into six sectors in table1 and food product industries are divided into seven sub-sectors in table2[12]. Population and sample size of industry has been distributed as table 1.

Primary data are obtained from questionnaires, survey/observation from September to November, 2016 for energy demand and solar PV resources assessment in the study area. Further, GIS and Google earth mapping are also used for verification of solar resources assessment. Similarly, secondary data that were taken from relevant documents and reports of Nepal Electricity Authority, Nepal Oil Corporation and Industrial District Management; are used for cross checking the primary data.

Table 1: Population and sample distribution of Industry according to sectors

SN	Sectors	Population	Sample
1	Food Product	29	12
2	Chemical, Rubber and Plastic Product	37	16
3	Other Manufacturing	15	7
4	Wooden Product	3	1
5	Electrical Eng. And Product	10	4
6	Mechanical Eng. And Product	28	14
	Sub-total	123	54

Table 2: Population and sample distribution of Industry according to food sub-sectors

SN	Sectors	Population	Sample
1	Dairy Product	3	1
2	Other Food Grain mills product	7	3
3	Grain mills	3	1
4	Cold store and Ice Cream	4	2
5	Beverage Industry	2	1
6	Feed Product	7	3
7	Poultry Farm	3	1
	Sub-total	29	12

Table 3: Population and sample distribution of Industry according to food sub-sectors

SN	Categorization of Area	Area (m2)	Remarks
1	Roof Area	60,194.77	
2	Wall Area	20,788.16	
3	Greenary Area	26,011.20	
4	Parking Area	28,038.81	
5	Land Scape Area	24,945.79	

The Average sunshine hours per day, average temperature and Solar Direct Normal Irradiation (DNI) for calculation of solar PV energy are taken from water and energy commission secretariat (WECS) report-2010. According to NEA report, the cost analysis has performed according to electricity time of day tariff for industrial area on base year 2016 [6].

The review shows Solar PV system with tie grid system without battery backup is best for industrial purpose

[13]. Whereas, average capital investment cost for Concentrated solar PV system and its components all together is NRs.210,000 per kW and Diesel generator's average cost is NRs.20,000 per kW which are taken as input to financial analysis[14].Subsidized interest rate on bank loan made through seven local bank for commercial project (greater than 1.5 kW) is 4.5% for 7 years[15] and [10].

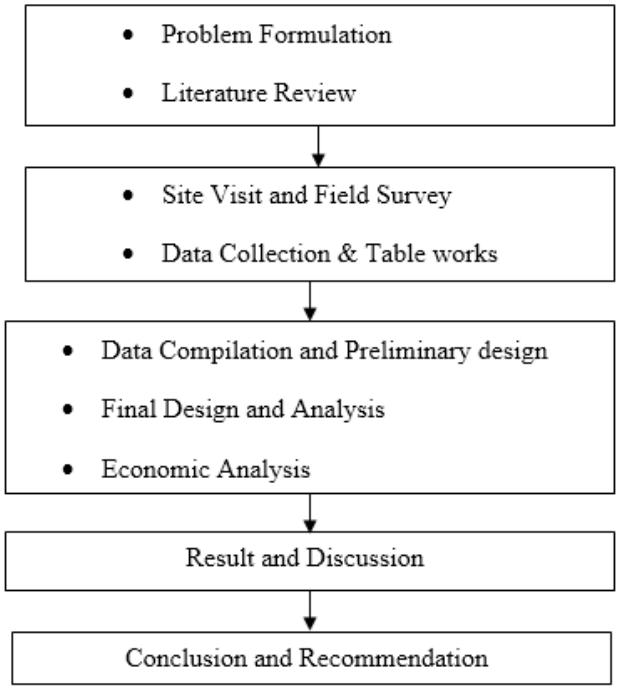

Figure 1: Flow chart of Research Methodology

Here the overall methodology has been developed which is shown in figure 1. Energy system is modeled by Homer Pro Simulator to check feasibility on technical and financial parameters. The energy purchased and sold are also calculated from simulator.

3. Results and Discussion

3.1 Electrical Energy Consumption

Out of 54 industries, the electric energy consumption in the industrial estate is shown in Figure 2 according to different sectors. Food product industry consumes about 50% (9959.429 MWh) electric energy followed by Chemical, rubber and plastic industry with 25% (5018.75 MWh) and remaining share in consumed by other industries.

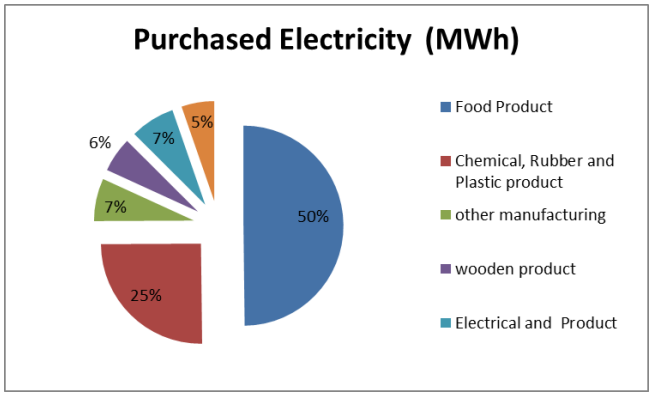

Figure 2: Sector wise average electric energy consumption (in 2016)

3.2 Diesel fuel energy consumed by Diesel Generator Set

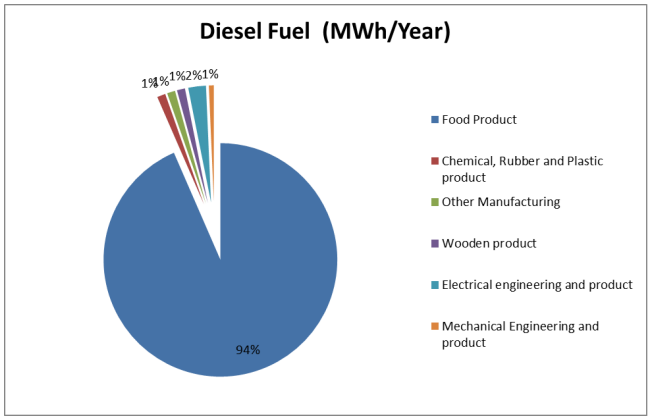

Figure 3: Sector wise average equivalent energy consumption of diesel fuel (in 2016).

Out of 54 sample industries, 12 industries were not using DG set. But when it comes to food sectors industry, the use of DG set is highest (94% of total) then others. Calculated average Annual equivalent total diesel fuel energy based on calorific value is about 13,746 MWh which is illustrated clearly in Figure 3.

3.3 Comparison between Average Purchase Diesel Fuel and Electricity consumption in 2016 for BID

Sector wise average purchase energy (both diesel fuel and electricity) is given in Figure 4.

a. Food Product: Figure 4 shows that the food product

industry consumed highest amount of total energy (either electricity or diesel fuel) and each are nearly equal. Average total energy (both Diesel fuel and electricity) purchase in dairy product sector is in average 5520.00 MWh and 466.20 MWh in year 2016.

b. Chemical, Rubber and Plastic Product: Average total purchase energy consumption was about 408.05 MWh/year by this sector. Among these values, only 94.37 MWh diesel fuel energy was supplied from equivalent diesel fuel energy.

c. Other Manufacturing: About 288.65 MWh/year equivalent average total purchase energy was supplied to other manufacturing industries. However, average diesel fuel energy was about 91.58 MWh/year among them.

d. Wood Product: Average energy from Diesel fuel about 91.57 MWh per year was supplied to this wooden product industry and 1130 MWh energy was recovered from the electricity.

e. Electrical Engineering and Product: In this sector, average total energy purchase was about 560.74 MWh/year. However, 200.22 MWh/year of average diesel fuel was consumed by this sector of industry and remaining from electricity.

f. Mechanical Engineering and Product: The lowest total value of purchase energy (132.03 MWh/ year) was consumed by this sectors' industry.

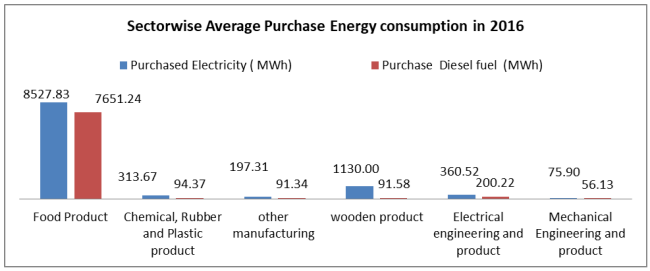

Figure 4: Average energy consumption by Sector in 2016

3.4 Sizing the Solar PV Grid Tied System

The average sizing of the Architectures of Solar PV grid tied without storage system has been tabulated in Table 4 for different sector of industry using Homer Pro Simulator. This size was calculated and showed in average size for various sectors.

Table 4: Average sizing of components of Solar PV grid tied system in sectors

Sectors	PV (kW)	Converter (kW)	PV-MPPT (kW)
Food Product	238.74	298.43	328.27
Chemical, Rubber and Plastic Product	113.06	141.33	155.46
Other Manufacturing	103.89	129.86	142.85
Wooden Product	491.93	614.92	676.41
Electrical Eng. And Product	396.34	495.43	544.97
Mechanical Eng. And Product	193.97	242.46	266.71
Sub-total	1537.94	1922.42	2114.66

Table 4 shows the total average size of PV is about 1537.94 kW, 1922.42 kW for converter and 2114.66 kW for PV-MPPT. All the different sectors were simulated and found technically feasible. Figure 5 shows the basic block diagram for Grid Integrated Solar PV System for Dairy Development Corporation. The sizes of main components are 598.45 kW of PV, 748.03 kW of Converter and 822.84 kW of MPPT.

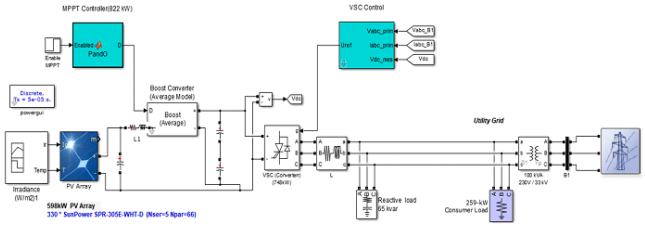

Figure 5: Basic block diagram for Grid Integrated Solar PV without storage System for Dairy Development Corporation

3.5 Technical Analysis

The following Points show the Solar PV tie Grid without storage system in BID is Technical Feasible which are discussed as:

- Climatic Condition: The climatic risk such as hail, strong winds, tornados etc. are very rare and thus do not need to be considered in the KTM. Dust and Pollution in the BID require regular cleaning of PV

modules. For the Balaju Industrial District in Kathmandu Valley, it is not necessary to calculate the horizon so as to assess shadows generated by hills.

- National grid connection: All the industry has same voltage level (220 V for single phase and 380 V for three phase supply), frequency (50 HZ). By using Pure Sine Wave Inverters, disturbance in the transmission signal due to harmonic should be kept to the acceptable minimum limits.
- Components availability: In Nepal, more than 59 companies sell photovoltaic modules and about 26 companies are approved by the AEPC, Government of Nepal. Thus, solar PV modules, MPPT, Converter etc. according to IEC 61215 or 61646 and safety IEC 61730-2 standards are easily available in Balaju Industrial District.
- Educational: There is the lack of competent technicians in the grid-connected sector to promote the grid installations. Majority of industry have Technician with Level-I and Level-II with knowledge of Solar Home System only. It should be made complete by providing the additional specific training for grid-connected PV system including technical details on grid-connected inverters, installation, protection etc.
- Resource available: The field survey and questioner found the roof-top space for solar PV are enough for most of industry.

3.6 Financial Analysis of Existing System and Proposed System

The summarization of financial analysis is illustrated in Table 5. Here, Levelized COE (4.69 NRs/kWh) is lowest for Chemical, Rubber and Plastic Product industry and 12.01 NRs/kWh is highest value for Electrical Engineering and Product industry after replacing the diesel generator in 2016 as shown in Table 5.

The study found that the proposed designed system has the LCOE NRs. 9.61 per kWh by using 10193.99 kW of Solar PV plant without storage system for 15 years in 2016 for 54 industries in Balaju Industrial Estate. According to report, LCOE of purely grid tied stadium PV plant (with battery storage) is found to be 12.50 per kWh for 20 years [16]. Where, the cost of storage device (for lead acid battery for 1-hours) in solar system is 14% of total system cost [17].

Table 5: Sector-wise summarization of financial analysis

Sectors	Total Investment (millions NRs.)	NPC (millions NRs)	Levelised COE (NRs/kWh)
Food Product	613.68	944.45	11.48
Chemical, Rubber and Plastic Product	511.92	3.81	4.69
Other Manufacturing	453.75	0.90	10.58
Wooden Product	407.74	46.93	6.89
Electrical Eng. And Product	417.76	165.81	12.01
Mechanical Eng. And Product	401.40	15.27	12
Sub-total	2806.23	1271.65	*9.61

Note: * for average Levelized COE

Calculation and simulation was done by using ground level data, and data was validated from authorize organization.The study has shown NRs.12.5 per kWh of levelized COE is for tie grid of solar system in Dasarath stadium at 4.5 % discount rate [16]. Levelized COE is Rs.14.94/ kWh and 11.40/kWh for on-site and off-site pv power plant respectively considering 25 years plant life at 10% discount rate in Garment industry of India [18].It shows that the result from simulator and calculation are consistent. System design precision and NPC precision both 0 .01 are considered during optimization and sensitive analysis.

3.7 Total GHG Emission Reduced

Figure 6 shows total averge emission in tones of CO2e for different sector of industry. There is highest value of total emission (2380.04 Tons CO2 eq) in food product industry and 21.91 Tons CO2 eq is lowest for wooden product industry in 2016. Most of Carbon dioxide is produced from existing industry due to the diesel generator. For example, 629.137 tons of CO2e (about 98% of total emission) is produced in 2016 and low values 0.024, 0.173, 1.34,3.725 and 3.965 tons of CO2e per year are particulate matter, unburned hydrocarbons, sulfur dioxide and carbon monoxide respectively.

Further, the implementation of interconnection between Solar energy resource and NEA grid can minimize the emissions in our environment.

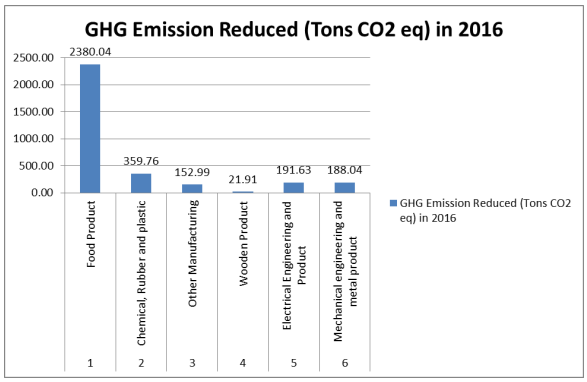

Figure 6: Summarization of total emission reduction by using Solar PV system.

4. Conclusion

- The total electrical energy consumption in Balaju Industrial Estate was found to be around 19,994 MWh in 2016.
- The total diesel fuel consumption in Balaju Industrial Estate was found to be around 13,746 MWh in 2016.
- Based on load consumption, roof area, solar insolation and photovoltaic system efficiency and Nepal Electricity Authority's selling and buying tariff rate, the average size of photovoltaic module, converter, photovoltaic-maximum power point tracker, was calculated to be 1,537.94 kW, 1,922.42 kW and 2,114.66 kW respectively using HOMER Pro Simulator.
- Total Net Present Cost and Average Levelized Cost of Energy (LCOE) were calculated to be around NRs. 1,886.41 Million and NRs. 9.61 per kW for an initial investment of NRs. 2,183.63 Million and Discount rate of 14% using HOMER Pro Simulator.
- It was found that the total emissions reduction after replacing diesel with solar PV system was calculated to be 3,294.37 tons CO2 equivalent in 2016.

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References

[1] http://www.idm.org.np/index.php/2014 12-30-08-23-17/balaju. Industrial development management(idm) limited (2016); bid. 2016.

[2] A. Shakya, S. Tamang, R. Pajiyar, and et al. Nepal's electricity crisis: Survey and findings: Update for 2013, 2013.

[3] The World Bank. Diesel power generation: Inventories and black carbon emissions in kathmandu valley, nepal. 2014.

[4] Water and Energy Commission Secretariat (WECS). Energy data sheet. type, institution, June 2014.

[5] M. Chandel, G. Agrawal, S. Mathur, and A. Mathur. Techno-economic anlayisis of solar photovoltaic power plant for garment zone of jaipur city. 2:1–7, 2014.

[6] Nepal Electricity Authority(NEA). Annual report, 2016.

[7] NEEP. promoting cogeneration in nepal adding a new source to the electricity mix. 2013.

[8] K. R. Adhikari, S. Gurung, and B. K. Bhattarai. *Solar Energy Potential in Nepal and Global Context*. 1st edition, 2011.

[9] Nepal Oil Corporation (NOC). Annual report, June 2016.

[10] Alternative Energy Promotion Center(AEPC). Renewable energy subsidy policy, 2016.

[11] Robert V. Krejcie and Dryle W. Morgan. Activities. 38:607–610, 1970.

[12] WECS. Update and compilation of energy resources and consumption profile of nepal: Final report vol-i and vol-ii. type, Water and Energy Commissionn Secretariat(WECS), 1997.

[13] Y. Chu. *Review and Comparison of Different Solar Energy Technologies, annual report*. 2011.

[14] http://www.eia.in/ref/ae/sol/rooftop/cost. Eia consulting services (2017) cost of concentrate solar pv module, eia. 2017.

[15] Nepal Nepal Investment Bank Limited. Interest rate for renewable energy, 2016.

[16] AK. Shakya and J. Shrestha. Case study on grid integrated solar pv for national dasarath stadium. pages 322–332. Proceedings of IOE Graduate, 2015.

[17] Dobos A. DiOrio N. and Janzou S. Economic analysis case studies of battery energy storage with sam. pages 67–68, 2015.

[18] M. Chandel. *Techno-economic analysis of solar photovoltaic power plant for garment zone of Jaipur city', Case Studies in Thermal Engineering*. 2014.