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Cost Saving Potential of Grid-tied Solar Photovoltaic-based Hybrid Energy System in the Philippine Industrial Sector

Patrick Gregory Jara[a], Michael Castro[a], Eugene Esparcia Jr.[a], Carl Michael Odulio[b], Joey Ocon[a,*]

[a]Laboratory of Electrochemical Engineering (LEE), Department of Chemical Engineering, University of the Philippines Diliman, Philippines
[b]Power Electronics Laboratory, Electrical and Electronics Engineering Institute, University of the Philippines Dilima Philippines
jdocon@upd.edu.ph

The Philippine Industrial Sector contributes USD $124x10^9$ (~PHP $6.5x10^{12}$) or about 1/3 in the economy. However, the electricity cost, which is 2nd highest in Asia, constitutes up to 10 % of their total operating expenses. This hinders foreign direct investment to the country. Solar photovoltaic grid-tied hybrid energy systems are one of the emerging ways to reduce electricity expenses of the industrial sector. Current net-metering policy, which enables grid-tied systems, restricts the export of energy to the grid up to 100 kW_p with compensation equal to the average generation rate of the distribution utility. This work evaluates the techno-economic viability of putting up solar photovoltaic grid-tied hybrid energy systems for 66 randomly selected industrial establishments classified under electrical/electronics/semiconductors, steel/metal, food/beverages, transportation/logistics and textile/garment sub-sectors using Island System $LCOE_{min}$ Algorithm (ISLA). ISLA will provide the optimal system component sizes of solar photovoltaic and battery in the least levelized cost of electricity (LCOE) by performing hourly calculations for one reference year using actual load profiles. The results suggest 63 out of 66 sample industrial establishments are viable to put up solar photovoltaic grid-tied hybrid energy systems, with a total solar photovoltaic capacity of 783 MW_p. There are 7 establishments that are capable of off-grid solar photovoltaic-battery-diesel configuration. If export restriction in net-metering policy is lifted, the total solar photovoltaic potential will significantly increase up to 3,947 MW_p, which corresponds to LCOE reduction to USD 0.14 (~PHP 7.2) per kWh and increase in renewable energy share to 34 %. This work shows that tapping solar rooftop potential and amending the net-metering policy increases operational savings of the Philippine industrial sector.

1. Introduction

The industrial sector is one the main driver in most economies. In the Philippines, the industrial establishments contribute USD $124x10^9$ (~PHP $6.5x10^{12}$) worth of income (Philippine Statistics Authority, 2012). However, the high electricity cost, which is 2nd highest in Asia, raised major concerns from the local industry which constitutes up to 10 % of the operating expenses (European Commission – European Competitiveness Report, 2014). Resolving this matter will hasten the economic growth of the Philippines and attract more foreign direct investments. One of the emerging and preferred way to reduce electricity expenses is the use of solar PV-based systems (Abidin et al., 2017). Implementation of solar PV based hybrid systems by industrial establishments should reduce their electricity costs, but these investments should be assessed for efficiency as some sectors may be not profitable depending on their level of energy demand and energy use behaviour of the facility (Chiaroni et al., 2014). For countries like the Philippines, where the energy industry is regulated by the government, the economic viability of solar PV-based systems also highly depends on regulatory policy scenarios (Spertino et al., 2018). In this work, the techno-economic viability of solar PV-based energy systems for industrial sector within the Manila Electric Company (MERALCO) was investigated accounting the relevant

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Philippine policies, economic parameters and actual energy data from the industrial plants. This study will provide the framework needed to assess the feasibility of solar PV installation for industrial plants.

2. Methodology

Techno-economic analyses of the selected industrial establishments were done using the Island System $LCOE_{min}$ Algorithm (ISLA) to simulate energy systems and calculate optimum configuration and sizes. ISLA is an open-source Python-based energy systems tool to optimize the least cost solar PV hybrid system combination and is validated with HOMER Energy (Ocon et al., 2017). The tool was already used to assess solar PV hybrid implementation for Off-grid areas in the Philippines (Ocon et al., 2018). This work covers 66 randomly selected sample establishments from the following industrial plant categories within the MERALCO franchise area: Electrical/Electronics/Semiconductors (15 samples); Steel/Metals (13 sample); Food/Beverages (13 samples); Transportation/Logistics (13 samples); and Textile/Garments (12 samples). The actual energy demand and energy use profiles or load profiles from MERALCO were used for optimization and simulation. The analysis will use the current net metering scheme (Status Quo), which is the current Philippine net metering policy that supports the implementation of grid-tied solar hybrid systems with export limit or cap of 100 kW and will be paid using the blended generation rate by the distribution utility (DU) (Energy Regulatory Commission, 2013). Previous studies show that there will be differences in the economic viability of implementing solar PV hybrid systems when certain regulatory policies such as the export limits are changed (Ghosh et al., 2014). Different scenarios such as a modified net metering scenario where the export limit is abolished but still be paid using the blended generation (Expanded Policy), a scenario using the maximum potential of the rooftop area (Maximum Roof Capacity) and an off-grid scenario using solar PV-diesel-battery energy configuration shall also be investigated. The rooftop area that can be utilized for solar energy was estimated manually using Google Maps™, with appropriate spaces for workers and possibility of shading were considered. The widely used economic parameter for renewable energy investments is the Levelized Cost of Electricity (LCOE) (Bortolini et al., 2014). Other economic parameters such as Net Present Value (NPV), Return of Investment (ROI) per year, and Payback Period (PBP) are also measured to be able to completely assess the investment efficiency of the solar PV investment (Lee et al., 2014). Renewable Energy (RE) share is also be obtained to identify the contribution to the renewable energy portfolio.

3. Results across the covered industries

The total results using ISLA under the different policy scenarios are shown on Table 1. Figures 1 and 2 show the average and projected capacities per industry type and scenario of all the sample industrial establishments.

Table 1: Over-all results on the implementation of Solar PV hybrid system to Industrial establishments.

	Status Quo (100 kW)	Expanded Policy	Max Roof Capacity
Average solar PV installed capacity (kW_p)	64	289	372
Total solar PV installed capacity (MW_p)	783	3,947	5,205
LCOE (PHP/kWh)	7.9	7.2	8.4
NPV (10^6 PHP)	649	418	419
ROI (%)	9.3	9.1	8.7
PBP (y)	11	11.1	12.2
RE share (%)	29	34	36

The results show an untapped solar potential of 783 MW_p on the rooftops of industrial establishments. This would be increased to 3,947 MW_p if the current export limit is expanded. Out of 66 sample industrial establishments, three (3) samples are deemed unviable due to shading. There are 27 establishments that have optimized rooftop solar PV capacities greater than the export limit in the current Philippine net-metering scheme with 2,312 kW_p as maximum value. This value may be used as benchmark in expanding the export limit of the current policy.

There are 28 industrial establishments that have rooftop solar PV capacities less than the maximum roof capacity, which on average the solar hybrid installation requires 41 % of the maximum roof capacity. Only 7 establishments are viable for off-grid systems using solar PV-diesel-battery configuration where the average energy storage capacity for off-grid scenario is 115 kWh using lithium-ion battery.

Figures 3 to 7 show the comparison of different techno-economic parameters per industrial end-user categories at different policy scenarios. In all industries, the LCOE values are below the average retail electricity price (~PHP 10 /kWh) within the MERALCO franchise. The Expanded Policy scenario improves the LCOE values from an average of PHP 7.9 /kWh to PHP 7.2 /kWh suggesting that policy change in the net-metering scheme

improves cost savings for the industrial sector. Both Status Quo and Expanded Policy scenarios exhibit high ROI values with an average of 9.3 % and 9.1 % and with low PBP values of 11 years which suggest economic viability of the system. Harnessing the maximum rooftop solar potential has lowered the ROI to 8.7 % and increased the PBP to 12.3 years because large investment capital requirement is not offset by the cost savings generated. The RE share increases based on the calculated sizing and demand of the establishment as expected.

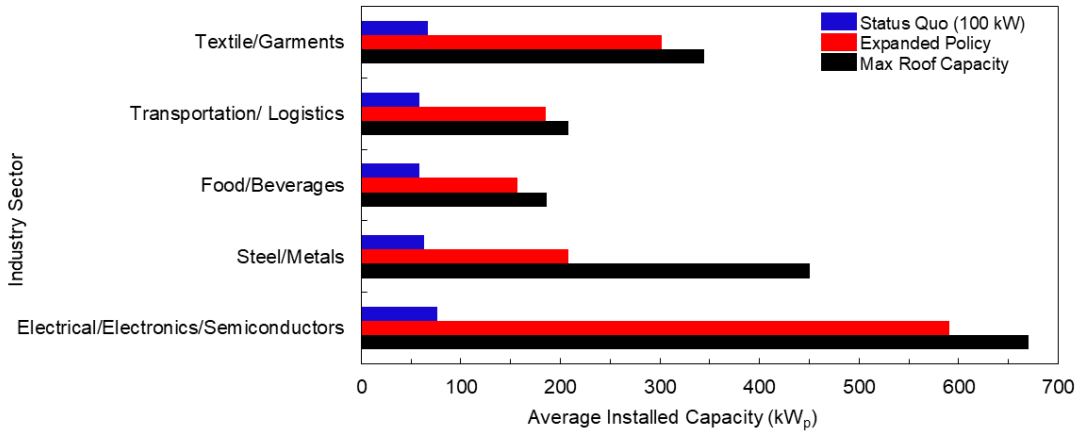

Figure 1: The average rooftop solar PV installed capacity of industrial establishments under different policy scenarios.

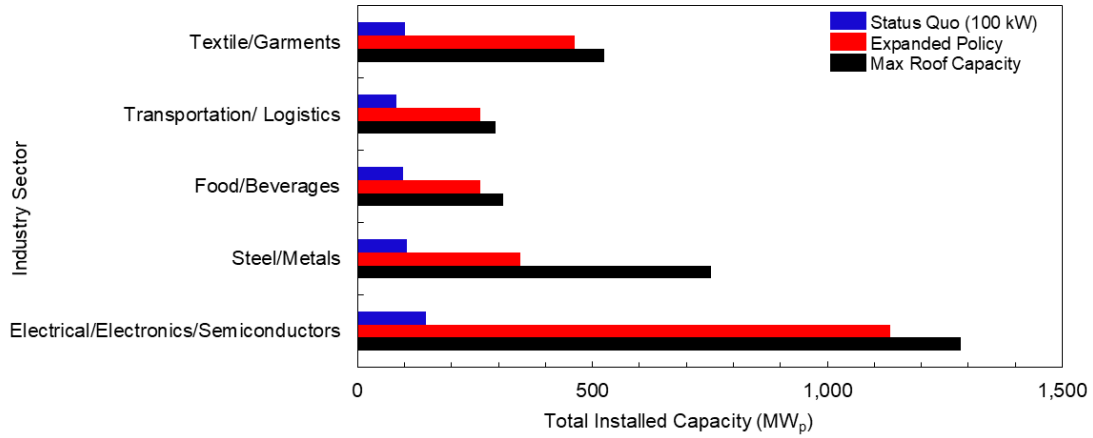

Figure 2: The total rooftop solar PV installed capacity of industrial establishments under different policy scenarios.

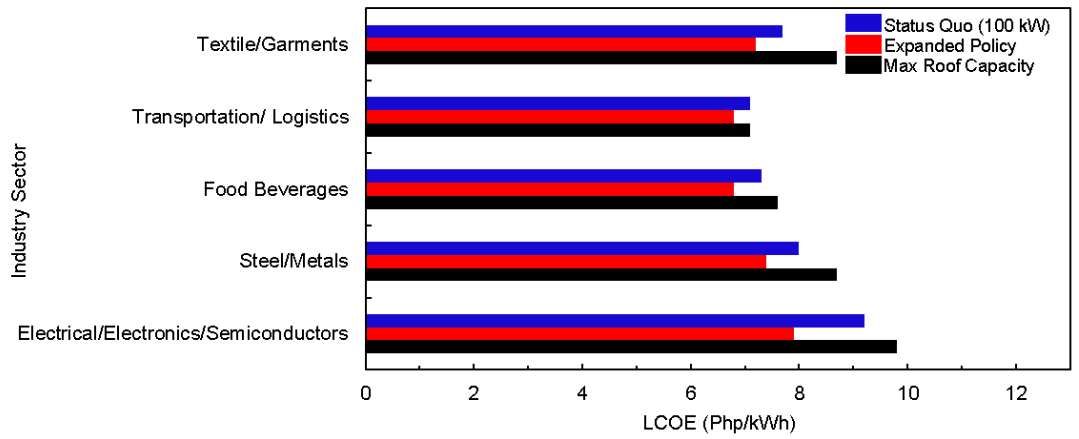

Figure 3: Comparison of LCOE in different industrial end-user categories at different policy scenarios.

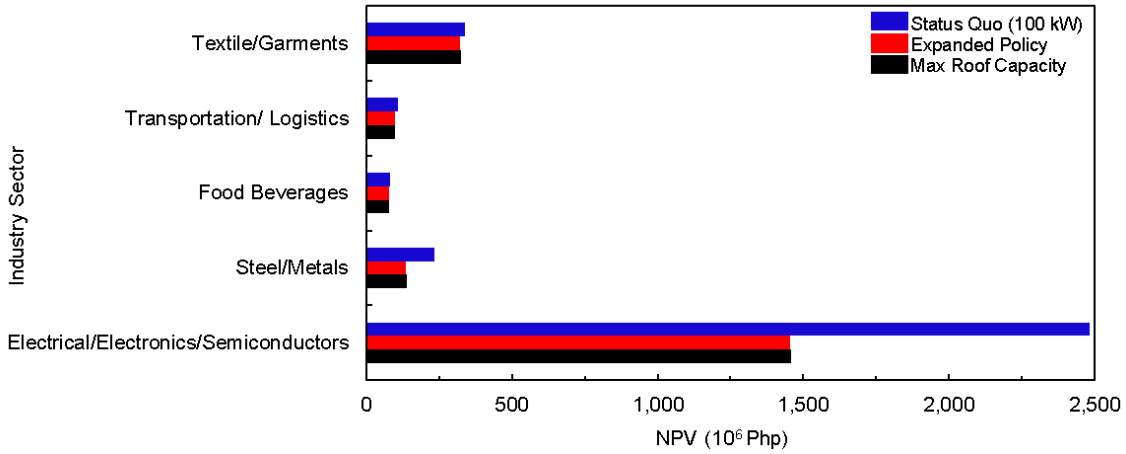

Figure 4: Comparison of NPV in different industrial end-user categories at different policy scenarios.

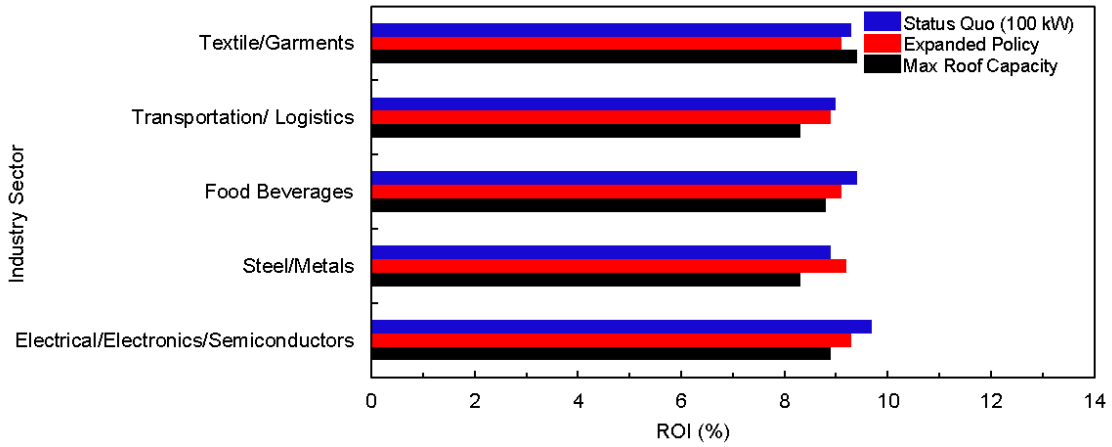

Figure 5: Comparison of ROI in different industrial end-user categories at different policy scenarios.

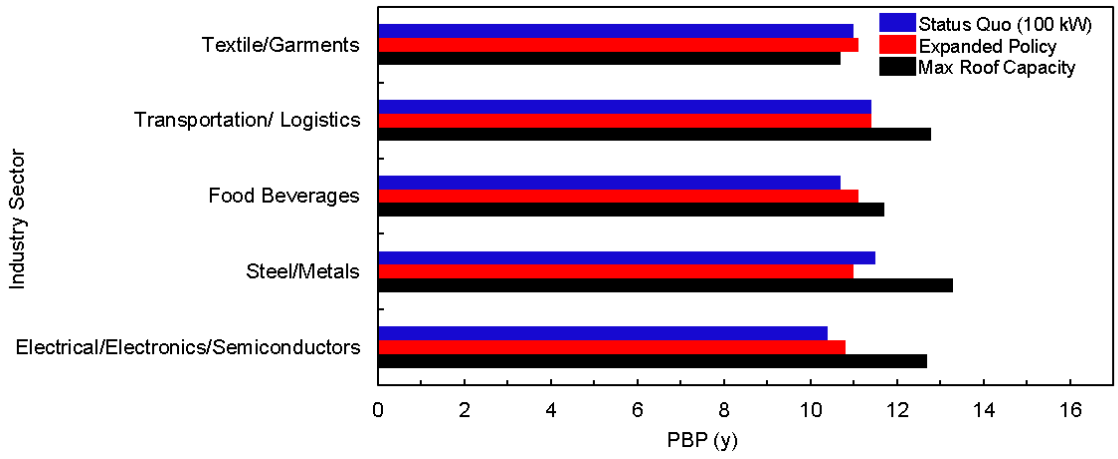

Figure 6: Comparison of PBP in different industrial end-user categories at different policy scenarios.

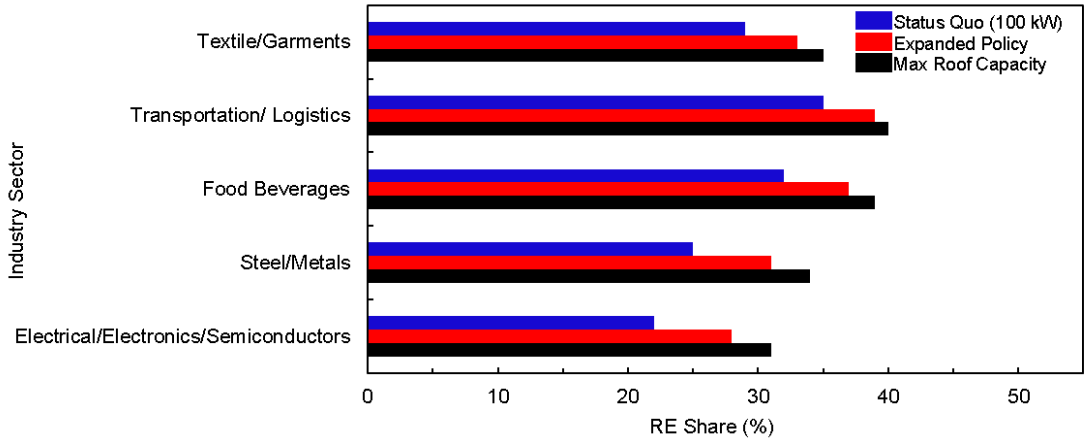

Figure 7: Comparison of RE Share in different industrial end-user categories at different policy scenarios.

4. Case Study: Steel Plant

Table 2 provides the detailed results using ISLA and Figure 8 illustrates the solar PV capacity per scenarios. Significant improvement in LCOE is evident if export restriction is abolished from PHP 9.23 /kWh (Status Quo) to PHP 5.98 /kWh (Expanded Policy). Harnessing the maximum roof potential will further reduce the LCOE to PHP 5.89 /kWh. The ROI per year shows highest returns for Status Quo and Expanded Policy scenarios at 9.6 % and 9.3 % while Maximum Roof Capacity scenario exhibits low returns at 4.6 % due to high investment costs. High ROI indicates faster period to recover investment as shown in the PBP values. The sample steel plant is not viable for solar PV-diesel-battery off-grid scenario due to the variability in its load profile.

Table 2: Results on Economic parameters of the case study using ISLA.

Economic Parameter	Grid	Status Quo (100 kW)	Expanded Policy	Max Roof Capacity	Off-grid
LCOE (PHP/kWh)	10	9.23	5.98	5.89	17.47
NPV (10^6 PHP)	95.8	88.7	57.4	56.6	167.8
ROI (%)	-	9.6	9.3	4.6	-
PBP (y)	-	10.5	10.8	21.8	-
RE share (%)	-	16	42	46	-

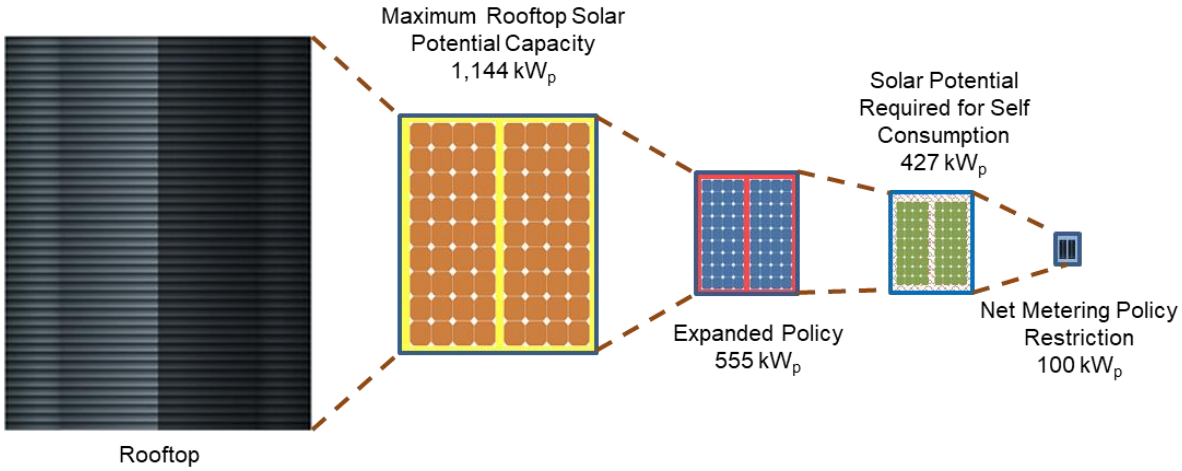

Figure 8: Graphical illustration of sample steel plant in different policy scenarios.

5. Conclusions

This work proposes a framework that can be used by industrial establishments to assess solar PV hybrid system for industrial establishments based on their rooftop area, energy demand, energy use, and the current policy scenario. This framework is needed by the sector to assess the efficiency of solar PV investments as maximizing their rooftop area is not always economically viable. Using the optimal sizes of solar PV generated by the proposed methodology on the implementation of solar PV hybrid systems will result to electricity cost savings on the part of the industrial plants based on the reduction of the LCOE and NPV. Efficiency of these investments can also be ensured by using other economic assessment parameters such as ROI and PBP as indicated in this study. Results across the five sub-industries suggest that there is an untapped rooftop solar potential that can be harnessed by the Philippine industrial sector. This will expand the country's renewable energy sector as additional energy supply will be available without the need for constructing additional ground-based power plants. The resulting total installed capacity that can be tapped from solar PV installations can replace the current base load coal power plants. This can aid the Philippines energy and environmental regulators as these contributes to the Philippine climate change mitigation initiatives by reducing dependency on fossil-based power plants. Finally, this work clearly shows that expanding the current net metering scheme policy should result to increased installed capacity which will further improve profitability and increase impact to the reduction of carbon emissions.

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