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A Techno-Economic Assessment of Small Energy Access Microgrids in the Philippines

Patricia Baricaua[a], Eugene Esparcia Jr.[a], Carl Michael Odulio[b], Joey D. 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 Diliman Philippines
jdocon@up.edu.ph

In an effort to expedite the electrification in off-grid areas in the Philippines, the Qualified Third Party (QTP) scheme encourages private sector to engage in power generation and distribution business through competitive selection, a process that requires at least two rival bidders with rigorous registration requirements. An exemption is offered for microgrids with sub-100 kW capacity by not undergo competitive selection in order to further attract investors and private sector to engage in these off-grid areas since these areas are deemed highly unviable. The Department of Energy opened around 995 areas waived by electric cooperatives for third party servicing. The sub-100 kW capacity can serve areas with fewer than 500 household connections, which fits the profile of the 995 areas. In this work, the techno-economic feasibility of installation of sub-100 kW microgrids is done in order to know the required level of subsidies, loans, and/or grants to sustainably operate in these areas. The proposed microgrids were evaluated using ISLA, an open-source microgrid optimizer validated by HOMER Pro, by finding the optimal system component sizes of solar PV, battery, and diesel generators with the least levelized cost of electricity (LCOE). Initial results suggest initial investment cost for the establishment of 15 sub-100 kW microgrids ranged from USD 0.5 to 1 M (~PHP 25 to 55 M), with LCOE averaged at PHP 10.26/kWh. This corresponds to 30 % reduction relative to the LCOE from using diesel generator only. Strategies such as partial financing and full grant of capital expenditures show that the former can provide generation rates at par with typical generation rates of existing electric cooperatives at ~PHP 5 to 6 per kWh, while full subsidy can significantly reduce the generation cost to PHP 2 to 3 per kWh. Providing long term and low interest rates from financial institutions to fund these projects will help hasten the deployment of sub-100 kW microgrids. To achieve financial sustainability in these areas, productive use of energy through income generating projects should be highly encouraged in order to give the inhabitants the capacity to pay.

1. Introduction

There are still more than 2.36 M households in the Philippines that are yet to be electrified as of 2016. These are situated on islands, remote, or mountainous regions which are considered unviable and missionary (IRENA, 2017). According to the Philippine Development Plan 2011 - 2016, the Philippine economy continues to develop, and it is imperative that all Filipinos shall have access to basic necessities such as electricity as a tool to improve the quality of life and standard of living (IRENA, 2017). Full electrification in the country has been a challenge due to its archipelagic geography. In response to this, the Missionary Electrification Development Plan 2016 - 2020 by the Department of Energy (DOE) focuses on expediting the electrification by promoting private sector participation to electrify the remaining unenergized areas. One scheme that enables privatization is the Qualified Third Party (QTP), which opens to 3rd party providers the generation and distribution of electricity after undergoing competitive selection process (CSP) (DOE, 2016). This intends to establish independent micro- or mini- grids financed and operated by the private sector instead of the government.
Establishment of off-grid energy systems has already been employed to supply electricity, owing to the archipelagic and mountainous geography of the Philippines. Currently, around 215 off-grid systems managed by the government-owned National Power Corporation – Small Power Utilities Group (NPC-SPUG) supply

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manages the establishment of off-grid energy systems that supply the electricity to these areas not connected to the main grid. These power plants are mostly operated using diesel generators that offer retail prices much higher than grid electricity costs. Nonetheless, some studies in the Philippines explore the huge potential of utilizing renewable energy (RE) sources, particularly for solar energy. From a study conducted by Ocon and Bertheau, hybridizing the currently installed diesel plants to solar-battery-diesel systems can significantly reduce the LCOE by 19.6 % (Ocon and Bertheau, 2019). Microgrid calculations were conducted to determine the technical and economic feasibility of transforming the diesel systems into hybrid systems consisting of solar PVs and batteries coupled with the existing diesel genset. Transformation to hybrid systems reduces reliance on fossil fuels, promotes increase in RE usage, provides 24/7 access to residents and reduces emissions to the environment (Ocon and Bertheau, 2019).

While NPC-SPUG strives to cover all areas for electrification, the DOE has opened for the entry of 3rd party providers on servicing unviable areas expeditiously reach out to more areas. The 2017 memorandum by National Electrification Administration (NEA) mandates that all areas within the franchise scope of electric cooperatives (ECs), which have not been energized, must be waived for third-party providers to offer electricity generation and distribution services. Majority of unenergized areas are situated in West Mindanao, South Mindanao, and Bicol Region. As of 2018, about 995 areas have been waived for third-party providers, but very few investors have expressed intent in serving these areas (DOE, 2018). A study by IRENA explored issues surrounding the development of grids in the Philippines. Among the concerns raised are the (1) rigorous application process for the entry of potential QTP, (2) lack of technical know-how and understanding of renewable energy technology, (3) limited access to financing sources to establish and operate the grids, etc. It is recognized that these issues are barriers in accelerating the deployment of hybrid systems that are necessary to achieve 100 % electrification in the country.

The QTP guidelines were consequently revised aimed to attract investors to enter the market. To further promote their participation, an incentive is given to small-scale demand areas qualifying below 100 kW capacity such that a potential QTP need not undergo CSP. Most of the 995 areas that were opened for QTP are barangays, the lowest governmental unit. The profiles of most of these areas can fit the 100 kW requirement for the exemption and therefore a good starting point in attracting the entry of QTP.

Taking advantage of this incentive, techno-economic assessment of installing sub-100 kW microgrids is done in order to assess the feasibility of operation and determine the required level of subsidies, loans, and/or grants to establish and sustainably operate in these areas. The proposed microgrids were evaluated using Island Systems $LCOE_{min}$ Algorithm (ISLA), an open-source microgrid optimizer which is validated using HOMER Pro, by finding the optimal energy systems configuration with the least levelized cost of electricity (LCOE) possible. The study aims to profile the feasibility of microgrids in these areas to come up with a combination of technical data and financing model which can serve as a reference for potential QTP investors.

2. Methodology

2.1 Estimation of Load

Load profile was taken from typical residential load pattern from MERALCO, an electric power distribution company in the Philippines (Figure 1). Peak load was lifted from March 2018 performance report of the electric cooperatives, normalized with the served household connections (HHC) to derive a factor of peak load per HHC (Table 1). Number of unenergized HHCs are then multiplied to this factor to derive the estimation of the peak load of an area. From this, sub-100 kW capacities can cater to around 250 to 500 HHCs. This magnitude is suitable for *sitio* or small *barangay* (lowest administrative unit in the Philippines) which fits the profile of the 995 areas opened for QTP.

Table 1: Peak Load per HHC for select Electric Cooperatives (EC)

Electric Cooperative	Peak Load (kW/HHC served)	No. of HHC for 100 kW Peak Load
DASURECO (Davao)	0.35	285
CASURECO (Camarines Sur)	0.18	555
SORELCO (Sorsogon)	0.26	384
ZAMSURECO II (Zamboanga Del Sur)	0.32	312

2.2 Modeling the Microgrid Energy Systems

The proposed microgrids were evaluated using ISLA, an open-source microgrid optimizer by finding the optimal system component sizes of solar PV, battery, and diesel generators with the least levelized cost of electricity (LCOE). ISLA is validated using Hybrid Optimization Model for Electric Renewables (HOMER), a widely-used simulation software developed by the National Renewable Energy Laboratory that determines the best configuration or system architecture for a microgrid based on the levelized cost of electricity (He, et.al, 2017). HOMER considers the load profile, the available renewable and non-renewable energy resources, system components (such as solar PV, batteries, and generators), and economic factors (such as price of components, interest rates and lifetime) to design the optimal system and calculate the resulting LCOE. It defines LCOE as the average cost per kWh, $/kWh, of useful electrical energy produced and is calculated by:

$$LCOE = \frac{C_{ann,tot}}{E_{served}} \quad (1)$$

where $C_{ann,tot}$ is the total annualized cost ($/y) or the annualized value of the total net present cost and E_{served} is the total electrical load served by the system (kWh/y) (HOMER Energy, 2016).
Modeling of the configurations using ISLA determines the levelized cost of electricity (LCOE) through combinations of diesel genset, batteries and solar panels. In this study, three configurations were considered: (1) Diesel only (2) Solar PV and Li-ion Battery (3) Hybrid: Solar PV – Battery – Diesel. Solar GHI data was extracted from 2005 NASA Surface Meteorology and Solar Energy Database.

2.3 Techno-economic Parameters

Table 2 summarizes the techno-economic parameters used in optimization and simulation while Table 3 shows the peak load and current power cost of sample area per electric cooperative. These areas were arbitrarily chosen to cover 30 kW to 100 kW capacities for comparison. These parameters are input for the ISLA to evaluate the system architecture, capacities of each component and the corresponding LCOE and CAPEX required.

Table 2: Techno-economic parameters used in simulations

Comp.	Parameter	Unit	Value	References
Diesel	CAPEX	$/kW	500	
	OPEX (var)	$/kW h	0.03	(Blechinger, 2015)
	Fuel Cost	$/L	0.9	
	Lifetime	h	15000	
Solar PV	CAPEX	$/kW	1200	(Fu, et. al 2017)
	OPEX (fix)	$/kW y	25	
	Lifetime	y	20	(Blechinger, 2015)
Li-ion	CAPEX	$/kWh	300	(DiOrio et. al. 2015)
	OPEX (fix)	$/kWh y	3	
	Lifetime	y	10	(Moseley and Garche, 2015)
	RT. Eff.	1	0.90	
Project	Interest Rate	%	8	
	Inflation Rate	%	6	
	Lifetime	y	15	

Table 3: Peak Load and Power Cost of sample area per electric cooperative

Electric Cooperative	Area	Peak Load [kW]	Power Cost [PHP per kWh]
SORELCO	Esmerada	33.2	6.29
CASURECO	Caditaan	62.3	5.66
ZAMSURECO	Kasigpitan	81.9	6.60
DASURECO	Baluntayan	99.4	6.07

To assess the techno-economic feasibility of the sub-100 kW microgrid, three (3) energy systems configurations were considered in three (3) different financing strategies: No Subsidy, Partial Financing, and Full Financing. The Full Financing strategy relies on grants by private sectors wherein the capital expenditures (CAPEX) have all been covered and cost of electricity is reliant on operational expenses (OPEX). Partial Financing strategy considers 50 % CAPEX covered while No Subsidy strategy accounts all CAPEX and OPEX in the LCOE calculation.

3. Results and Discussions

Table 4 shows the LCOE requirement while Table 5 shows the CAPEX of different financing strategies and different energy systems configuration of four electric cooperatives. In general, the calculated LCOE across the different peak loads vary by ~PHP 1 per kWh and averaged at PHP 10.26 per kWh. The hybrid systems offer the lowest LCOE for all financing case scenarios, and deviation from diesel-only systems becomes more pronounced as capital expenditure is reduced. The use of hybrid systems maximizes the delivery of solar power coupled with batteries to address intermittency while relying on the diesel generator for base load, thereby reducing the operational costs from using diesel fuel. In terms of CAPEX however, diesel-only systems require significantly lower initial costs than systems with solar PV or BESS. This supports why off-grid electrification in the country rely mostly on diesel power plants because of the low investment cost required to establish these plants. Establishing a 100 % RE system such as solar PV-BESS, though offering lower LCOE, may be less appealing due to the high CAPEX required as a result of oversizing of batteries and solar PVs to compensate from the lack of base load from the diesel genset. Nonetheless, partial or full financing especially for missionary electrification reduces both the initial capital costs and LCOE for hybrid systems, and therefore becomes more economically attractive.

Table 4: LCOE requirements for different sub-100 kW capacities (in PHP/kWh)

Financing Scenario	Configuration	SORELCO	CASURECO	ZAMSURECO	DASURECO
No Subsidy	Diesel	10.00	9.97	10.02	11.31
	Hybrid	16.80	16.96	17.14	16.78
	Solar PV-BESS	15.12	14.53	14.18	14.10
Partial Financing	Diesel	6.44	6.40	6.50	6.50
	Hybrid	10.10	10.12	10.66	10.14
	Solar PV-BESS	14.95	14.36	13.83	13.92
Full Financing	Diesel	2.14	2.13	2.16	2.17
	Hybrid	2.74	2.75	2.80	2.82
	Solar PV-BESS	14.77	14.19	13.83	13.75

Table 5: CAPEX requirements for different sub-100 kW capacities (in million PHP)

Financing Scenario	Configuration	SORELCO	CASURECO	ZAMSURECO	DASURECO
No Subsidy	Diesel	19.07	35.40	49.40	55.79
	Hybrid	36.07	70.45	96.30	108.35
	Solar PV-BESS	0.96	1.79	2.57	2.86
Partial Financing	Diesel	10.33	19.54	27.40	30.92
	Hybrid	18.57	35.22	48.15	54.8
	Solar PV-BESS	0.48	0.90	1.29	1.43

Figure 2 summarizes the comparison of LCOE values in different financial schemes. In all financing strategies, the hybrid energy system provides the lowest LCOE while diesel only system provides the highest LCOE. The capital requirements of putting up sub-100 kW microgrids ranges from USD 0.5 to 1 M(~PHP 20 to 55M), with levelized cost at ~PHP 10.26 per kWh, which corresponds to 30 % reduction relative to the diesel generator system only.

The average LCOE for different financing scenario suggests that Partial Financing can be at par with the Subsidized Approved Generation Rate (SAGR), which is set by the Energy Regulatory Commission, at ~PHP 5.11 per kWh. Government subsidies amounting to PHP 30 million can finance a 100 kW microgrid that can offer competitive pricing for generation cost. Meanwhile, Full Financing strategy is possible through grants and donations by different sectors such as local government units, development assistance agencies, and private sector. Although investing in solar PV and batteries require higher CAPEX, the energy system provides the lowest LCOE due to low operational cost of solar PV relative to diesel generators only.

In terms of the capacity to pay of the residents, most of the unviable areas particularly in DASURECO rely on farming and agriculture of corn for livelihood. From the study of the Philippine Statistics Authority (PSA) on the Trends in Agricultural Wage Rates, the average income of corn farmers is PHP 246.05 per day, earning ~PHP 7,000.00 monthly. In another study on typical income class expenditure (Philippine Statistics Authority, 2019), around 7.2 % of the income of the bottom 30 % income class is allotted to utilities (water, electricity) – amounting to around PHP 500.00 to PHP 700.00 monthly for income range PHP 7,000.00 - PHP 10,000.00. Assuming half for each utility, monthly budget allocated for electricity is PHP 250.00 - PHP 350.00. To put into perspective, a sample household consuming 48.84 kWh for typical appliances (Table 4) can manage to pay their monthly usage at an average budget of PHP 300.00 if the retail rate is around PHP 6.14 per kWh. Sample household energy values are based on the 2011 Household Energy Consumption Survey on the Philippines conducted from March to August 2011 where 62.5 % of the household respondents belong to income class of less than PHP 10,000.00 monthly. The survey reports that the top three end-uses for electricity are lighting, recreation and space cooling (DOE & NSO, 2011). From the results, offering an LCOE near the SAGR, such as through Partial Financing strategy, can make the microgrid economically sustainable and the residents are able to afford their electricity use.

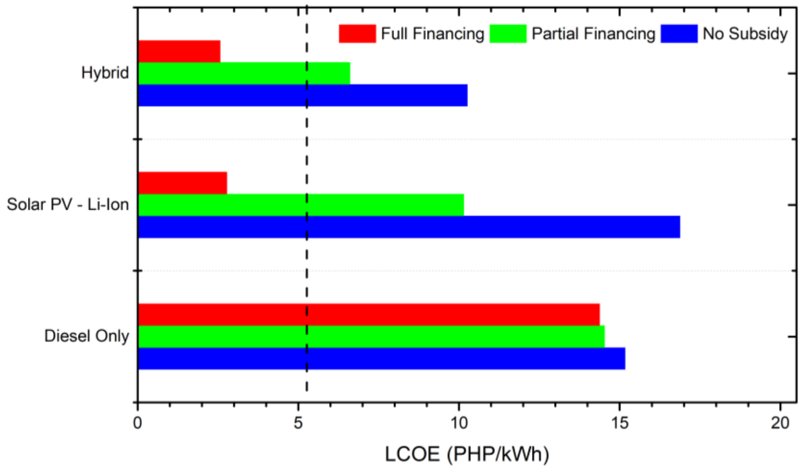

Figure 2: Case scenarios of LCOE simulations (dash: SAGR – PHP 5.11 per kWh)

Table 4: Sample calculation for household power consumption

End-use	Type of Appliance	Average 6-month consumption per household (kWh) (DOE & NSO, 2011)	Average monthly consumption (kWh)
Lighting	Compact Fluorescent Lamp	37	6.17
Recreation	Colored TV	103	17.17
Space Cooling	Electric Fan	153	25.5
Total/month			48.84

The results should provide a ballpark insight for many stakeholders. In general, any financial support to hasten the deployment of these declared unviable areas provides better solution both from the customers and the financiers. To further boost the capacity of the residents to pay for energy cost, priority is given to include income-generating projects appropriate to the area to ensure sustainability of the project. Aside from the techno-economic viability to put up QTPs, resolving other issues such as long processing of permits from the government hasten the microgrid development.

4. Conclusions

The techno-economic feasibility of sub-100 kW microgrids were evaluated for the electrification of some of the unviable areas in the Philippines. The load profile (i.e. less than 100 kW capacity) of 995 areas waived for QTP participation fit the exemption requirements for direct entry of microgrids and therefore a good starting point to energize these remote areas. Off-grid systems simulated using ISLA reports 30 % decrease in the generation cost using hybrid microgrid against diesel systems, with capital costs projected from USD 0.5 to 1 million (~PHP 20 to 55 million). Hybrid systems prove to be technically feasible in competing against diesel systems due to cleaner and more sustainable renewable energy sources used, and the lower reliance to fossil fuels. Financing strategies in terms of subsidies and grants were also explored to determine the level of funding required for a sustainable operation of these microgrids. Even with partial financing, the resulting LCOE of the hybrid system can be at par with the average grid cost which makes it more economically feasible than a diesel-only system. This paper hopes to provide techno-economic insight on the potential of 995 unelectrified areas in the Philippines for electrification and to serve as reference for potential QTP investors. Future works will include exploring the techno-economic evaluation of microgrids with limited operation (i.e. less than 24 h operation) which is expected to require less CAPEX, and therefore a good starting point in energizing the unviable areas. The steady decline of initial costs for solar PV and batteries may also be explored to determine how the financing shall be impacted in the long run. On top of this techno-economic study, it is recommended that the application process for QTP be further streamlined and simplified to expedite entry of 3rd party investors. Access to financing through partnership with development banks, non-government organizations and crowd-sourcing can also open opportunities for funding. Aside from residential electrification, priority should be given to income-generating projects to boost the economy of the remote area, and therefore increasing the residents' capacity to pay.

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