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AN ENERGY SYSTEM EVALUATION OF RURAL ELECTRIFICATION OF BARANGAY PURAY, RODRIGUEZ, RIZAL, PHILIPPINES

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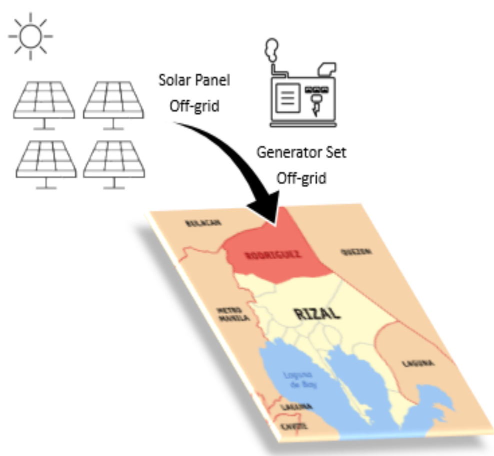
Graphical abstract



Abstract

Rural electrification in the Philippines is one of the main problems in the country. In this study, the possible electrification of Barangay Puray using three alternatives, namely, solar power, generator set and Meralco connection was analyzed. The stakeholders in this study were the people of the barangay, the local government of Rizal and the Meralco Corporation. Some assumptions are made, one of which is that the local government of Rizal will pay the capital costs for solar power and generator set, while the residents of the barangay will pay the government within 25-year period of the study. Here, two cases were introduced, whether the residents will pay the capital and maintenance costs or the maintenance costs only. The values of the initial costs and maintenance costs were compared and used to get the generation cost of the system. The results showed different values, with total of 189,889,720 pesos for the solar power while for the generator set was 235,425,304 pesos, thus the conclusion was made for the perspective of each of the stakeholder. For the residents of Barangay Puray, the most feasible was the solar power utility system. For the local government of Rizal, the generator set was more advantageous. While the Meralco Corporation would need the road laid out first before the electrification even it only has capital cost of 10,721,984 pesos in which the MOE was disregarded.

Keywords: Rural electrification, solar panel utility system, generator system, on-grid, off grid

1.0 INTRODUCTION

Last December 2016, President Rodrigo Duterte signed the General Appropriations Act wherein the off-grid areas for the nationwide household electrification will be prioritized in the program. The government allotted 1.1 billion budgets, an increase of 38.4 from its 2016 budget for the electrification efforts for remote areas [1]. This is to enable the Filipinos in provinces and far-flung areas so that they can be capable and prolific stakeholders in uplifting our societies and trades [2]. Electrification via off-grid focuses on the economic aspects in terms of financial sustainability [3]. Many rural electrification projects have failed due to lack of attention to the issues beyond financial and technical dimensions [4]. Real data from an off-grid microgrid in the Philippines were analyzed and used for simulating different sharing scenarios and presents a combined approach applying geospatial analysis, cluster analysis and energy system modelling [5, 6]. But a clear need for novel approaches for addressing this challenge [7].

Puray is one of the most isolated Barangay of Rodriguez (formerly known as Montalban) in the province of Rizal found in the mountain ranges of Sierra Madre [8]. This barangay is several mountains away from the town center which makes living in the vicinity difficult. Despite this situation, the community does farming in small scale in order to sustain livelihood and welfare. The citizen within the area has no means to access electricity and therefore, they use mostly kerosene lamps, candles, firewood and makeshift gas lamps in order to provide illumination at night and at dawn. The need for light becomes a burden because they spend one third of their daily income as an expense to sustain this. In the morning, most of the households commonly use the natural lightings from the sun, even if their houses were commonly made up of mud and bricks. The other resident houses were built in a 2-storey structure in which comprises complete different rooms, such as kitchen room, bedrooms and bathrooms. The rest of the residents of Barangay Puray mostly has single room (studio type).

Location

Puray is located in the Sierra Madre Mountains as shown in Figure 1, approximately 31.5 km from Quezon City which is about an hour and a half drive from Quezon [9]. The location houses, the Puray Falls, also known as Tungtong by the locals that is one of the attractions of the barangay.

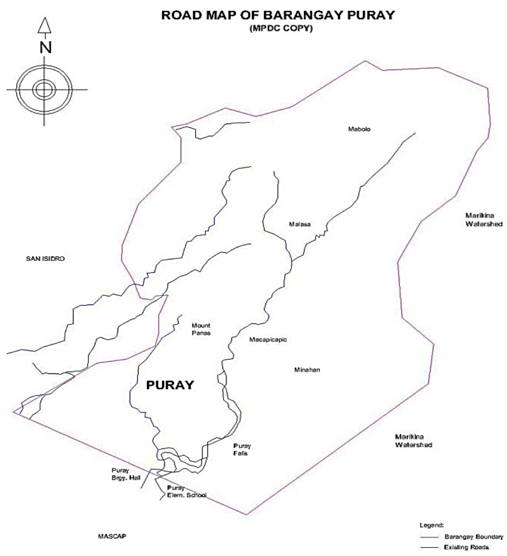


Figure 1 Road Map of Barangay Puray. Reprinted from the Office of the Municipal Planning and Development Coordinator (MPDC) of Rodriguez, Rizal, Philippines. Reprinted with permission.

Land Area

Barangay Puray has a total land area of 10,427.59 hectares and composed of 11 Sitio's namely: Macapicapic, Malasia, Mabulo, Bagong-Sigla, Bagong-Silang, Kinabuhuan, Quinao, Malasia Uyungam, Macaingalan, Ilas, and Lubo.

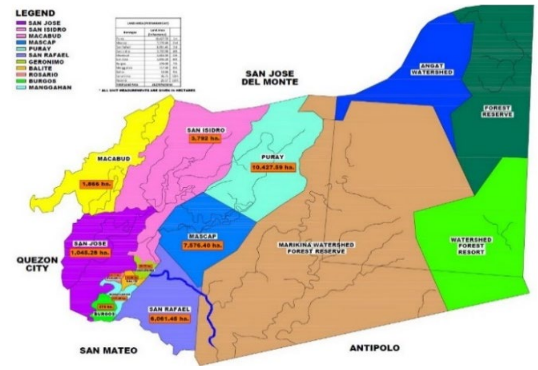


Figure 2 Land area of Barangay Puray. Reprinted from the Office of the Municipal Planning and Development Coordinator (MPDC) of Rodriguez, Rizal, Philippines. Reprinted with permission.

Economic Profile

Most of the locals is living below poverty line, thus, they earn an average income of Php 3,000.00 every month. Their primary sources of income are farming such as rice, ginger, cassavas, and banana, fishing, charcoal making and hunting wild animals as shown in Figure 2 with the large land area of Barangay Puray.

Population

The graph in Figure 3 depicts the population increase in the barangay of Puray, which was based on a data from the World Bank, which indicates that the Philippines has an average population growth rate of 1.6 % [10]. There is a gradual increase of locals within the area starting from 4,717 people of year 2017 to 6,795 in 2041 by the end of the 25-year period. The demographics of the city are composed of mostly indigenous people primarily the Tribal People Dumaga Remontado and the rest of the inhabitants are locals originating from the city proper [11].

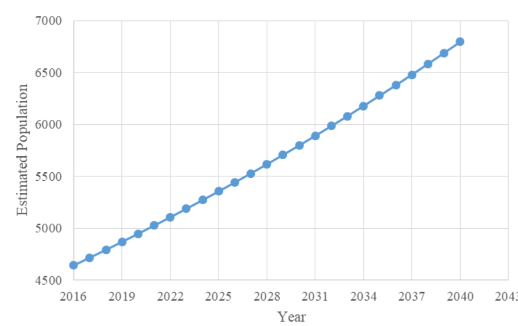


Figure 3 Population trend of Barangay Puray from 2017 to 2041

As of the signing of the General Appropriations Act 22 on December 2016, all off grid areas will be prioritized in the national intensification and household programs [2]. Subsequently, a proposition of building electricity lines and energy storage within Barangay Puray is sought for the use of the community. In order to check and validate the sustainability of the project, an economic analysis in this study will be made between the proposed alternatives as mentioned in the methodology which checks the cost, performance, operations and management of the project as well as projected demand.

In these research, a decision analysis with the three electricity source alternatives will be done with respect to the lowest overall capital investment criteria. High capitalization in the rural electrification program are required when considering renewable energy technologies specially in determining the possible sustainability and efficiency of the targeted beneficiary of an alternative electricity source [12, 13]. Overall, this study will be significant in rural areas which has limited supply of electricity.

2.0 METHODOLOGY

The fundamental question addressed in this analysis was how the Barangay Puray will be electrified. The three alternatives in this study were the following:
1. Solar Power (Off-grid)
2. Generator Set (Off-grid)
3. Meralco (On-grid)

All stakeholders in this study were joined in the first and second objectives and were maximized the number of households electrified while minimizing the cost of electrification. At the time of study, only Meralco would have the objective of maximizing their profit, unless the Barangay will make their own cooperative in the future.

The stakeholders in this study together with their objectives were shown in Table 1.

The influence diagram that was developed for this study was shown in Figure 4 below followed by the discussion of each node in Table 2.

Table 1 Stakeholder and their objectives

Stakeholders	Objective 1: Maximize the number of households electrified	Objective 2: Minimize the cost of electrification	Objective 3: Maximize profit
Residents of Barangay Puray	x	x	
Local municipality of Rizal	x	x	
Meralco Corporation	x	x	x

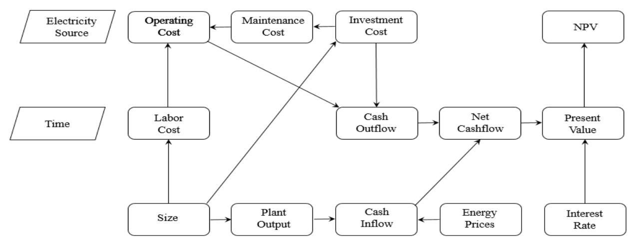


Figure 4 Influence diagram

Table 2 Detailed Breakdown of Nodes

Node Name	Unit	Node Type	Definition and Assumptions
Electricity Source	-	Index	This was an index of the alternatives, namely, solar power, generator set and Meralco connection. These alternatives were considered due to the demography and feasibility of the electrification.
Time	yr	Index	This was an index of time (in years) that goes up to 25 years (chosen based from the life span of solar and generator set). Electric source assumption ran continuously – 24 hours a day, 7 days a week – at full operational capacity. The study started in 2017 and ends in 2041.
Operating Cost	Php/yr	Variable	The operating cost here was the sum of labor costs and the maintenance costs.
Maintenance Cost	Php/yr	Variable	The maintenance cost here differed by the type of electricity source. For the solar power, the maintenance cost was made up of charge controllers, batteries and other inverters. For the generator set, it was made up of diesel cost, overhaul and routing costs. For Meralco, the maintenance cost was variable and included in the cost of their electricity. Thus, there was no maintenance cost included for Meralco.
Investment Cost	Php/yr	Variable	Investment cost was the initial cost of acquiring the system. The initial cost for solar and generator set were shouldered by the local government of Rizal. These gave the two cases for the study. The first case was when the residents of barangay would pay the investment and the maintenance cost of the systems. The second case was when the residents would only pay for the maintenance cost for solar and generator set and their electric bills from Meralco.
Size	km^2	Variable	This was the amount of land that was used by the electrification.
Energy Prices	Php/ kWh	Variable	The price of energy for solar and generator set was based from the two cases stated in the investment cost. Meralco had their own price scheme. This produces one of the uncertainties of the project, since it does not account for the possible price changes in diesel or the changes in the generation charge of Meralco.
Interest Rate	-	Variable	Interest rate was considered to be 3%.
Net Present Value	Php	Variable	The present value of the investment taking into consideration the time value of money

Load and Energy Forecasts

In this section, the load and energy forecasts for the whole barangay within the span of 25-year period was discussed. The analysis in this section was based primarily on two different sources of information. First, the NSO data of the population of Barangay Puray and second, economic and demographic data pertinent to the project area given by the Municipal Hall of Rodriguez, Rizal.

Estimating Model

The population of Barangay Puray in 2016 was 4,642. With 1.6% increases in population for the Philippines from 2011-2015, the estimated population of Barangay Puray as projected for the 25-year study was shown in Table 5. For the consumer usage model, the estimation was differentiated into two components, lighting and appliance as shown in Table 3 below. This was based on the total area of 24 m^2, with lighting load of 28VA per m^2 while the small appliances at 180 VA per convenience outlet was used. The consumption was computed in Table 4, in which the flat iron represents the largest wattage consumption, and LED light bulbs to be the least. Overall consumption per household would generate at least 1200 watts.

Table 3 Design Analysis for Model Estimation

Design Analysis	
Total Floor Area	24 m^2
General lighting load at 28VA per m^2	= (28 VA)(24 m^2) = 672 VA
Small appliance at 180VA per convenience outlet	= (3 outlets)(180 VA) = 540 VA
Total	1212 VA = 1212 W = 1.2 kW

For a sample house that would consume 1.2 kW per day, Table 4 indicates the overall list of appliances and lighting typically used. For this study, the assumed average number of hours for the use of electricity was 10 hours. This gave an average power consumption of 12kWh per day or 360kWh per month for every household. However, it should be noted that these values were already high compared to average usage in urban households. This was to have a projection of the maximum possible power usage of every household in the area. The actual usage can be much lower than 12kWh per day. As part of sensitivity analysis, the number of hours to be used of electricity would be varied.

Table 4 Consumption per Household

Appliance	Wattage	Quantity	Total Wattage (Watts)
TV (LED)	90 watts	1	90
Electric fan (desk fan)	40 watts	2	80
Lights (LED)	15 watts	2	30
Flat iron	1000 watts	1	1000
		TOTAL	1200 watts

In the Table 5 below, the load forecast for Barangay Puray for the 25-year study was shown. The population for 2016 was based from actual NSO census while the other years were projected based from the 1.6% growth rate of the Philippines. The estimated number of households was done in order to give the energy prices per household. This was computed by dividing the estimated population by five, then rounding up the result to a whole number. The theoretical load capacity was computed by multiplying the number of households by 1.2 kW. The actual load capacity accounts for the losses in the generation of electricity and can be derived by dividing the theoretical load capacity by a factor of 0.8.

Based from these values, in 2041, the barangay can reach an energy requirement of 2MW. Thus, from this projection, the installation of a 2MW power system in 2017 will incur less cost compared to buying additional system every year with lower energy capacity. In this regard, the 2MW system design for solar power, generator set and Meralco connection was used.

Table 5 Energy Load Forecast for the Barangay Puray

Year	Estimated Population	Estimated no. of households	Theoretical Load Capacity Needed (kW)	Actual Load Capacity Needed (kW)
2016	4642	929	1114.8	1393.5
2017	4717	944	1132.8	1416
2018	4792	959	1150.8	1438.5
2019	4869	974	1168.8	1461
2020	4947	990	1188	1485
2021	5026	1006	1207.2	1509
2022	5106	1022	1226.4	1533
2023	5188	1038	1245.6	1557
2024	5271	1055	1266	1582.5
2025	5355	1071	1285.2	1606.5
2026	5441	1089	1306.8	1633.5
2027	5528	1106	1327.2	1659
2028	5617	1124	1348.8	1686
2029	5706	1142	1370.4	1713
2030	5798	1160	1392	1740
2031	5890	1179	1414.8	1768.5
2032	5985	1198	1437.6	1797
2033	6080	1216	1459.2	1824
2034	6178	1236	1483.2	1854
2035	6277	1256	1507.2	1884
2036	6377	1276	1531.2	1914
2037	6479	1296	1555.2	1944
2038	6583	1317	1580.4	1975.5
2039	6688	1338	1605.6	2007
2040	6795	1359	1630.8	2038.5
2041	6904	1381	1657.2	2071.5

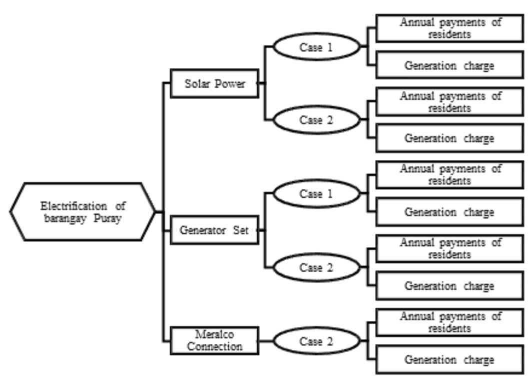


Figure 5 Decision tree

Decision tree shown in Figure 5 was used in deciding for the possible electrical connection in Barangay Puray. Decision tree was a tree-like structure that models possible outcomes and possible consequences that includes different branches which represents decision-making steps that could lead to a favorable results. In this study, the parameters involved were the three alternatives such as the Solar Power, Generator Set and the connection in Meralco (Electric company provider), annual payments of residents and its corresponding generation charge would be considered in the determining the best option in

Barangay Puray, Rodriguez Rizal. There would be two cases each for Solar Power and Generator Set, while for the Meralco connection there would be one. A subsequent amount would be determined in each of the parameters for annual payment of residents and generation charge. The finality of the best alternative electric connection would depends on the total cost.

3.0 RESULTS AND DISCUSSION

The feasibility of the projects for solar panels, generator system and Meralco connection was elaborated and discussed below. The capital cost for solar and generator set would be shouldered by the local government unit of Rizal through government or non-government loans presently available. The Meralco would also pay for the initial cost of putting up the posts and transmission lines. However, for the Meralco to successfully put up their connections, road systems along Barangay Puray should be made.

In that case, the two cases in this study were the following:

Case 1. The residents would pay the installation cost and the maintenance and operating expenses of electrification.

Case 2. The residents would only pay the maintenance and operating expenses for the solar and generator set and their electric bills from Meralco.

In case 1, let's say the local government can only loan for the people but they cannot donate the system, so the people would have to pay for the initial payment made by the government. This was only applicable for the solar power and generator set. For case 2, the local government would initiate the donation of the system but would leave the maintenance and operating expenses for the people to continue. However, for case 2, since the MOE of Meralco was not known, the payment basis would only be from the electric bills that would be given to the consumers.

The study focused on the most feasible type of electrification for the Barangay based on the initial cost, maintenance and operating cost and the generation charge. Then the environmental impact of the system was incorporated.

Solar Power Utility System

This part showed the breakdown of the cost for a solar power utility system for case 1 and case 2. This included the costing for the solar panels, installation charges, mounting charges, cost of inverters and other peripherals. The cost included the cost of solar panels at 35%, inverters at 6% of the capital cost which includes other auxiliary items such as DC-AC inverters, charge controllers, and batteries [14, 15]. This would be the total capital cost and be valued in the Case 1 and Case 2. The proposed 2 MW solar power utility system will be generating for 25 years, amounting to 153,783,732.08 pesos of capital cost both in the two cases as shown in Table 6.

Table 6 Two MW Solar Power Utility System for Capital Cost

Component	Cost (Php)	Life (yrs)	Net Present Value Case 1 (Php)	Case 2 (Php)
Interest Rate	3%	25		
Solar Panels (2 MW Solar Module (35% of the capital cost))	53,824,306	25	-53,824,306	-53,824,306
Installation(25% of the capital cost)	38,445,933	25	-38,445,933	-38,445,933
Mounting (10% of the capital cost)	15,378,373	25	-15,378,373	-15,378,373
DC-AC Inverters (6% of the capital cost)	9,227,024		-9,227,024	-9,227,024
Peripherals (Charge controller, batteries, and other electrical connections (24% of the capital cost))	36,908,096		-36,908,096	-36,908,096
Total Capital Cost			-153,783,732	-153,783,732

The maintenance and operating expenses were shown in Table 7. The cost of mounting and other expenses that includes personnel to operate and maintain the panels were also included in the analysis. The 2 MW Solar Power Utility System would be spending around 36,105,987.93 pesos for MOE.

Table 7 Two MW Solar Power Utility System for Maintenance and Operating Expenses

Component	Cost (Php)	Life	Net Present Value Case 1 (Php)	Case 2 (Php)
Interest Rate	3%	25 years		
Inverters (DC-AC)	9,227,024	10 years	-11,568,320	-11,568,320
Peripherals (Charge controller)	1,666,000	5 years	-4,539,684	-4,539,684
Peripherals (Batteries)	20,000,000	10 years	-25,074,868	-25,074,868
Annual pay for 3 attendants	383,250	Annual	-6,491,436	-6,491,436
	Total MOE		-36,105,988	-36,105,988

This part was the difference between case 1 and case 3 with regards to the total cost. The 2 MW Solar Power Utility System will be earning around 189,889,720 pesos and 36,105,988 pesos for the variable cost which represents the annual payment of the residents in Case 1 and Case 2, respectively. But the total cost was breakeven for Case 1 while for Case 2, still the 2 MW Solar Power Utility System will be spending around 153,783,732 pesos, which come from the direct effects of the difference in the annual payment of residents between the two cases as shown in Table 8.

Table 8 Two MW Solar Power Utility System for Total Cost

	Capital Cost (CC) (Php)	Maintenance and Operating Expenses (MOE) (Php)	Total Fixed Cost (TFC) = CC + MOE (Php)	Total Variable Cost (TVC) (Php)	Total Cost = TFC + TVC (Php)
Case 1	-153,783,732	-36,105,988	-189,889,720	189,889,720	0.00
Case 2	-153,783,732	-36,105,988	-189,889,720	36,105,988	-153,783,732

Centralized Generator System

Table 9 showed the breakdown of the cost for a centralized generator system. The capital cost includes the generator set and the installation cost. The bulk of the costing of generator set was on the maintenance and operating expenses. This includes the operating cost of diesel fuel consumption, routing service cost, top cylinder overhaul, replacement cost, engine overhaul and the salary of the three attendants that will maintain the system. In this study, the fluctuations of prices of diesel in not considered. The price used was Php 31.28 from May 1, 2017 price of diesel [16]. The overall capital cost for the 2 MW Centralized Generator System between Case 1 and Case 2 would be spending around 3.76 Million pesos. All were with a lifespan of 25 years.

Table 9 Two MW Centralized Generator System for Capital Cost

Component	Cost (Php)	Life (yrs)	Net Present Value Case 1 (Php)	Case 2 (Php)
Interest Rate	3%	25		
Generator Set (Includes the initial investment, installation, transportation)	3,600,000.00	25	-3,600,000.00	-3,600,000.00
Installation Cost (Includes freight cost and installation)	160,000.00	25	-160,000.00	-160,000.00
Total Capital Cost			-3,760,000.00	-3,760,000.00

While the largest maintenance and operating expenses came from the diesel fuel consumption and the routine service and maintenance cost annually, amounting to 7.36 Million pesos and 6.5 Million pesos, respectively. The least maintenance and operating expenses (MOE) was in the top cylinder overhaul amounting to 188,000 pesos annually. While the largest maintenance expenses only come from replacement cost of spare parts of the generator set as stated in Table 10

Table 10 Two MW Centralized Generator System for Maintenance and Operating Expenses

Component	Cost (Php)	Life (yrs)	Net Present Value Case 1 (Php)	Case 2 (Php)
Interest Rate	3%	25		
Operating cost (Diesel fuel)	7,364,736	Annual	-121,432,297	-121,432,297
Routing Service Cost	6,300,000	Annual	-103,876,564	-103,876,564
Top Cylinder Overhaul	188,000	Annual	-3,099,809	-3,099,809
Replacement Cost	612,000	3	-3,256,635	-3,256,635
Engine Over Haul	225,600	3	-1,200,485	-1,200,485
Annual pay for 3 attendants	383,250	Annual	-6,491,436	-6,491,436
Total MOE			-231,665,304	-231,665,304

While Table 11 below, indicated the total cost for Case 1 and Case 2, in which a breakeven cost was produced in Case 1. There was an expenses for Case 2 amounting to 3.76 Million pesos, even if the Two MW Centralized Generator System has an earnings of 231,665,304 pesos which comes from the annual payment of residents for Case 2.

Table 11 Two MW Centralized Generator System for Total Cost

	Capital Cost (CC) (Php)	Maintenance and Operating Expenses (MOE) (Php)	Total Fixed Cost (TFC) = CC + MOE (Php)	Total Variable Cost (TVC) (Php)	Total Cost = TFC + TVC (Php)
Case 1	-3.76 M	-231,665,304	-235,425,304	235,425,304	0.00
Case 2	-3.76 M	-231,665,304	-235,425,304	231,665,304	-3.76 M

Meralco Connection

The costs for Meralco connection was made up the distribution charges for transformers, poles, towers, fixtures, overhead conductors and devices, services, installation and tool cost. For case 2, the electricity bill of the residents that would be given to them by Meralco will be the amount that they will pay. This was with the assumption that each household consumes the maximum power usage that was allotted to them which was 360kWh per month. Also, the fluctuations on the generation charge of Meralco was not accounted and the price used was Php 9.65 for the month of May 2017. Overall capital cost for Case 2 for the Meralco connection which has expense of 10,721,984.39 pesos for 25 years as shown in Table 12.

Meralco would shoulder the expenses for and will not pass this cost directly to the residents of Barangay Puray but will be distributed among all their customers as shown in Table 13 for the variable cost. That was why the Meralco connection was not included on the case 1 study.

Table 12 Meralco Connection (Case 2)

Component	Cost (Php)	Life (yrs)	Net Present Value (Php)
Interest Rate	3%	25	
Distribution Transformers	2,402,730	25	-2,402,730
Poles, Towers and Fixtures	3,024,881	25	-3,024,881
Overhead Conductors	1,233,290	25	-1,233,290
Overhead Devices	183,429	25	-183,429
Services	100,366	25	-100,366
Installation	3,634,324	25	-3,634,324
Total Cost	142,966	25	-142,966
Total Capital Cost			-10,721,984

The total cost for the Meralco Connection will generate an income as much as 715,197,316.56 pesos. Mainly because all residents of Barangay Puray will just pay the annual payment for the KWH they used. Barangay Puray will have no MOE because of this and this will be the expenses for the distribution of electricity supply by Meralco.

Table 13 Meralco Connection (Case 2) for Total Cost

	Capital Cost (CC) (Php)	Maintenance and Operating Expenses (MOE) (Php)	Total Fixed Cost (TFC) = CC + MOE (Php)	Total Variable Cost (TVC) (Php)	Total Cost = TFC + TVC (Php)
Case 2	-10,721,984	0.00	-10,721,984	725,919,301	715,197,317

Table 14 Cost of Capital and Maintenance for the Three Alternatives

	Solar Power (Php)	Generator Set (Php)	Meralco (Php)
Capital Cost	153,783,732	3,760,000	10,721,984
Maintenance and Operating Expenses	36,105,988	231,665,304	N/A

The Table 14 above shows the summary of the capital cost and maintenance and operating expenses for the three alternatives. The solar power has the highest amount of capital cost of 153,783,732 pesos while the generator set has the highest amount of maintenance and operating costs of 231,665,304 pesos. This values will be further analyzed when the Case 1 and Case 2 is taken into consideration. Meralco will just shoulder the capital cost for the distribution of electricity amounting to 10,721,984 pesos. Maintenance and operating expenses was disregarded.

Table 15 The payment of residents annually and generation charge for Case 1 and Case 2

Alternatives	Payment of Residents Annually (Php)		Generation Charge Per Kwh	
	Case 1	Case 2	Case 1	Case 2
Solar Power	11,210,960.95	2,131,673.17	2.79	0.53
Generator Set	13,899,351.12	13,677,363.26	3.56	3.41
Meralco	N/A	41,688,000.00	N/A	9.65

Table 15 shown, the comparison of annual payments of residents and the generation costs for the three alternatives. For Case 1, only solar power and generator set can be compared while in Case 2, the three alternatives can be compared with each other. The highest generation cost was Meralco with Php 9.65, next was the generator set with values around Php 3.5 and solar with the lowest value at Php 2.79 for case 1 and Php 0.53.

Using the decision tree as shown in Figure 6, we can analyzed the impacts of each parameters for every case for the generation charge and the annual payment of residents of Barangay Puray which can help further in the decision of what will be the suitable alternative electricity source.

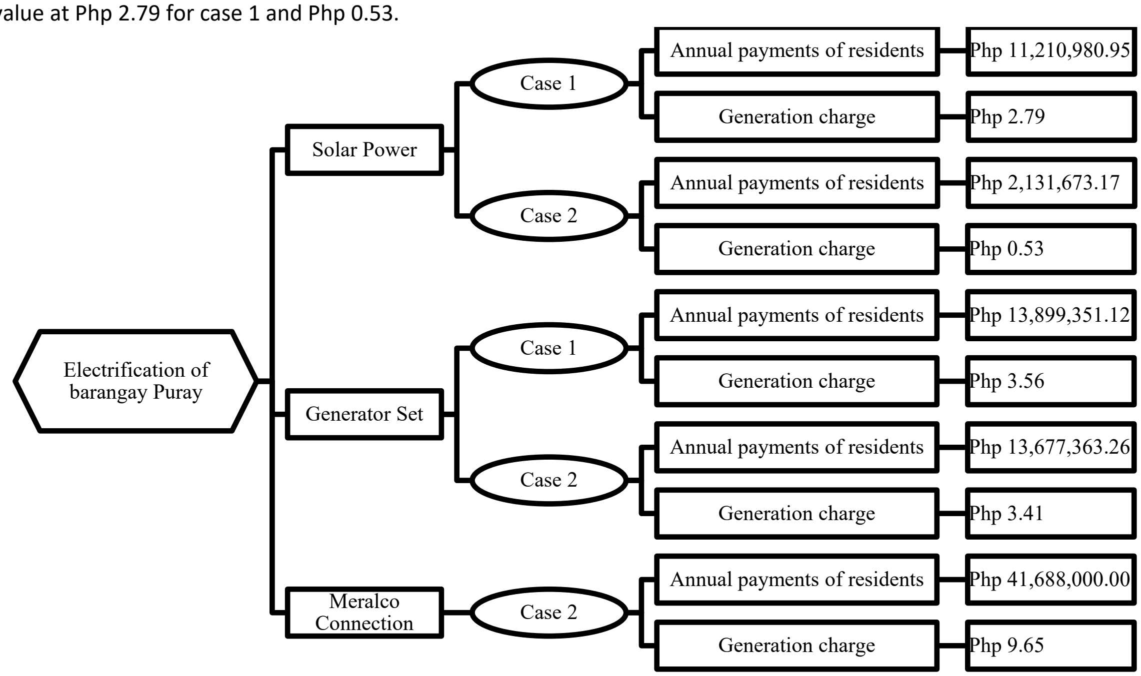


Figure 6 Decision tree with values for annual payment of residents and generation charge for the three alternatives

4.0 CONCLUSION

The project entails multiple attributes such that one conclusion cannot generalize the result. Thus, for every stakeholder, different conclusions and recommendations has been made as follows:

One assumption made in the start of the project was that the residents of the Barangay Puray would have to pay for their electrification in the span of 25 years. Two cases were made, in case 1, they would pay for the capital and MOE of the system. While in case 2, they would only pay for the MOE. In this light, the people would prefer to have an electrification system that will give them the lowest amount to pay for annually. Thus, the best option will be Solar Power Electrification for Barangay Puray residents.

The Local Government of Rizal would pay for the capital costs of solar or generator set. Thus, they would like to minimize this cost by choosing Generator Set Electrification.

The Meralco has the lowest capital cost compared to solar power and generator set, however the Meralco electrification can only be possible upon the presence of roads throughout the barangay which must be coordinated to the local government of Rizal or DPWH. Also, Meralco has the lowest environmental impact compared with solar and generator set. If this will take time to pursue, the Meralco can help in providing Solar Power for the barangay for the mean time.

The authors recommends the Barangay Puray area to provide other means of developing a sustainable electricity source other than solar, and generator system, like converting their wastes as an alternative fuel source [17, 18].

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References

[1] NEA initiates bold STEP towards electrifying 2.4-M households [Online]. Available: https://www.nea.gov.ph/ao39/phocadownload/ENERNEA/2018/enernea_2ndq2018.pdf [Accessed: March 2019]

[2] Del-Río-Carazo, L., Acquila-Natale, E., Iglesias-Pradas, S., and Hernández-García, Á. 2022. Sustainable Rural Electrification Project Management: An Analysis of Three Case Studies. *Energies.* 15: 1203. DOI: https://doi.org/10.3390/en15031203

[3] Mizanur Rahman, Md., Paatero, J.V., and Lahdelma, R. 2013. Evaluation of choices for sustainable rural electrification in developing countries: A multicriteria approach. *Energy Policy*. 59: 589-599. DOI: https://doi.org/10.1016/j.enpol.2013.04.017

[4] Prevedello, G., and Werth, A. 2021. The benefits of sharing in off-grid microgrids: A case study in the Philippines. Applied Energy. 303:117605. DOI: https://doi.org/10.1016/j.apenergy.2021.117605

[5] Bertheau, P. 2020. Supplying not electrified islands with 100% renewable energy based micro grids: A geospatial and techno-economic analysis for the Philippines. *Energy*. 202: 117670. DOI: https://doi.org/10.1016/j.energy.2020.117670

[6] Dibaba, H., Demidoc, L., Vanadzina, E., Honkapuro, S., and Pinomaa, A. 2022. Feasibility of rural electrification and connectivity—A methodology and case study. *Applied Energy.* 315: 119013. DOI: https://doi.org/10.1016/j.apenergy.2022.119013

[7] Puray Municipality of Rodriguez Province of Rizal [Online]. Available: https://www.philatlas.com/luzon/r04a/rizal/rodriguez/puray.html [Accessed: May 2019]

[8] Pasyal sa Rizal [Online]. Available: https://www.rizalprovince.ph/pages/tourism-nature.html [Accessed: March 2019]

[9] Philippines Population by Year [Online]. Available: https://worldpopulationreview.com/countries/philippines-population [Accessed: March 2019]

[10] Morales, D. The Remontados of the Sierra Madre Mountains [Online]. Available: https://ncca.gov.ph/about-ncca-3/subcommissions/subcommission-on-cultural-communities-and-traditional-arts-sccta/northern-cultural-communities/the-remontados-of-the-sierra-madre-mountains/ [Accessed: March 2019]

[11] Olalo, J., Dela Cruz, C. J., Bilang, R. G., Bonifacio, R., and Paringit, E. 2022. Determination of a Potential for the Installation of Small-Scale Wind Turbine in Barangay Bagasbas, Daet Camarines Norte, Philippines. *ASEAN Engineering Journal*, 12(1): 17-26. DOI: https://doi.org/10.11113/aej.v12.16503

[12] Lozano, L., and Taboada, E.B. 2021. Elucidating the challenges and risks of rural island electrification from the end-users' perspective: A case study in the Philippines. *Energy Policy*. 150: 112-143. DOI: https://doi.org/10.1016/j.enpol.2021.112143

[13] Tripp Lite Power Inverters [Online]. Available: https://www.tripplite.com/products/inverters-inverterchargers~18. [Accessed: March 2019]

[14] Wind Solar kits [Online]. Available: https://mwands.com/store/solar-charge-controllers, [Accessed: March 2019]

[15] Philippines Diesel prices [Online]. Available: http://www.globalpetrolprices.com/Philippines/diesel_prices/. [Accessed: March 2019]

[16] Olalo, J. 2021. Artificial Neural Network (ANN) Analysis of Co-pyrolysis of Waste Coconut Husk and Laminated Plastic Packaging. *ASEAN Journal of Chemical Engineering*. 21(2): 241-248. DOI: https://doi.org/10.22146/ajche.69521

[17] Manegdeg, F., De Silos, P.Y., and Medrano, J. 2021. A Case Study on the Usage of Residential Residual Waste for Energy Generation via Biodigester-Pyrolyzer and Steam Rankine Cycle. *ASEAN Engineering Journal*. 11(1): 13-23. DOI: https://doi.org/10.11113/aej.v11.16663

[18] World Bank. 2002. Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits. [Online] Available:https://openknowledge.worldbank.org/handle/10986/19890 [Acessed: April 2022]