Financial Analysis of a Hybrid Tidal Stream Energy System for Sustainable Island Electrification in the Philippines

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***Abstract*- Tidal Stream Energy (TSE) is emerging as an innovative solution to provide clean and reliable energy. TSE also has the benefit to conserve land, since the turbines are located in an offshore environment with strong tidal flows. This energy source has the opportunity to make a major difference in off grid areas, such as those found in the Philippines. As an archipelago of over 7000 islands, there are many "off grid" locations which are underserved or completely unserved with electricity.**

The Philippine government has instituted a missionary electrification program designed to help the many off grid locations throughout the country. However, providing electricity for the citizens of these locations is difficult due to the high cost of produced energy in remote areas. To assist in this, the government has created a Universal Charge for Missionary Electrification (UCME), which is a subsidy from developed areas distributed to missionary areas to improve the affordability of generated power. However, the subsidy algorithm is largely based upon the OPEX of diesel plants.

The research includes a case study of TSE implementation in a remote island area, San Antonio, Philippines. The use of real costs and HOMER simulation quantifies the costs related to CAPEX vs OPEX in a real TES project. The simulation and financial analysis further demonstrate that an electrification program based upon TES will include higher CAPEX costs and lower OPEX costs. Thus the simulation and financial study quantifies in real terms the need for governments to rethink their aid programs from OPEX assistance to CAPEX assistance, especially for sustainable island electrification for missionary areas like those found in the Philippines.

Keyword: Tidal Stream Energy , CAPEX, OPEX, MEP

I. INTRODUCTION

Tidal stream energy (TSE) offers an innovative solution for clean and reliable energy. Its inherent predictability and high capacity factor set it apart from other forms of renewable energy. Since it is caused by regular tidal cycles governed by gravitational forces of sun and moon and the rotation of the earth, its resource is not affected by weather and climate and does not have a problem of intermittency.

TSE can be extracted using hydrokinetic turbines (Jimenez and others, 2018). It is at the coasts where the energy flux is concentrated due to the interactions and reflections of the various tidal constituents between the deep oceans and coastal shelves, and coastal bathymetry, in particular with narrowing channels and estuaries (Vogel and others, 2019).

The Philippines is one of the countries which can potentially benefit from its abundant resource of tidal stream energy. It consistently experiences strong water flow and currents from surrounding deep ocean basins - West Philippine Sea (or South China Sea) to the west, the Philippine Sea and the Pacific Ocean to the east, and the Celebes Sea (or Sulawesi Sea) to the south. Strong archipelago throughflow is observed and it interacts with complex bathymetry producing a range of energetic flow regimes (Jones and others, 2011). Thus, tidal stream energy is naturally available around the island communities in the Philippines.

The Philippine Department of Energy has initially identified the following sites with the abundant resource: Hinatuan Passage, Camarines, Northeastern Samar, Surigao, Batan Island, Catanduanes, Tacloban, San Bernardino Strait, Babuyan Island, Ilocos Norte, Siargao Island and Davao Oriental. Buhali Jr (2012) assessed the preliminary tidal stream energy resource in the Philippines through a Delft3D hydrodynamic model calibrated from actual stream velocity measurements. They estimated a total of 46 potential TSE sites in the Philippines with a total practical capacity of 40 to 60 GW (Buhali Jr and others, 2012).

TSE can be harnessed and utilized in many remote and off-grid island and coastal communities in the Philippines where provision of basic electricity is not deemed commercially viable. Developing TSE systems in these off-grid areas will pave the way to universal access to clean energy through provision of sustainable energy solutions and decarbonization of the existing electricity generation.

A. MISSIONARY ELECTRIFICATION

The Philippines is an archipelagic country with more than 7,000 islands. The majority of its inhabited islands are not connected to the national grid due to technical and financial barriers (SEforall, 2019). As such off-grid electrification plays a key role in achieving universal access to energy. The National Power Corporation (NPC), a government agency, is mandated to provide electricity services to off-grid areas through its Missionary Electrification Program (MEP). Through MEP, the consumers' tariff is kept at a rate which is socially acceptable based on the customer class.

The need for the MEP is because the isolation of mini-grids and the use of diesel gensets on missionary areas leads to a high "true cost" of generation (IRENA, 2017a). Due to the cost of transporting the diesel to the islands, island diesel prices tend to be higher than on the mainland. The true cost of generation in missionary areas goes up to PHP 28,030 (USD 553) per MWh. Frequently, the consumers' tariff is kept at PHP 6,590 (USD 130) per MWh (Ahmed, 2017). The difference between the true cost of generation and the consumers' tariff is covered by a subsidy from the Universal Charge for Missionary Electrification (UCME) collected from the consumers in the mainland and managed by the government. However, as of 2021, the government is proposing a reduction and potential complete removal of the subsidies generated by the UCME program, driving the imperative for renewable energy.

B. The Need for a More Sustainable Energy Solution

Most of these missionary areas are being powered by old and inefficient diesel-fired generators resulting in high GHG emissions, local environmental pollution, unreliable and intermittent electricity supply, high cost of electricity generation due to high fuel transport cost, and high government spending for subsidies to cover the gap between consumer tariff and true cost of generation.

The study analyzed the data of the existing power plants in off-grid areas from data obtained from the DOE (2020) and NPC (2019). A total of 327 power plants, operating in 129 towns, were considered as missionary areas. These power plants have a total installed capacity of about 604 MW. About 94% of these power plants are dependent on fossil fuel and only 5% of them have started integrating ans using renewable energy into their systems. The study also found that only 133 plants (41%) can supply electricity for 24 hours in a day; 11 plants (3%) for 16 hours; and 124 plants (41%) for 8 hours and less. The Percent Power Interruption (forced outage rate) is 0.111% (NPC, 2019) which suggests a total of 5 hours power interruption daily can be experienced across off-grid areas.

Out of 1,515,836 households in missionary areas, 426,529 remain unelectrified as of June 2020 (NEA, 2021). The study also estimated that there are more than 1.3 million households across the Philippines still without access to electricity, based on the status of the Philippine Rural Electrification Program as of December 2020 (NEA, 2021).

In terms of the subsidy requirement for missionary electrification, the NPC requested a UCME of around USD 406.40 million in total to be collected from mainland consumers for the year 2021 (ERC, 2020). Around 46% of the UCME budget was allocated to subsidize the NPC Small Power Utilities Group (SPUG) operation which mainly uses diesel-based generation. For the year 2022, NPC's petition for a UCME subsidy for NPC-SPUG increased by almost 4% from the previous year. This is all within the context of government pressure to reduce and/or completely eliminate this subsidy.

Considering the environmental impact of the current missionary electrification, the study calculated the carbon emission of fossil fuel-based power plants in missionary areas for the year 2020 based on the 2020 estimated energy generation. Using the standard emission factor of 7.03 x 10-4 MT-CO2/kWh set by the US Environmental Protection Agency (2017), the study estimated that Missionary Electrification has contributed more than 2,284 metric tons of carbon dioxide in the year 2020.

The US Interagency Working Group on Social Cost of Greenhouse Gases estimated that the social cost of carbon(SCC) is USD 51.00 in 2020 dollars per metric ton of CO2 (IWG, 2021). SCC is "a metric designed to quantify climate damage, representing the net economic cost of carbon dioxide emissions" (Institute for Policy Integrity, 2021). Using this figure, the study calculated that 2020 carbon emission in missionary areas translates to about USD 116,491.

C. Private Sector Participation in the Missionary Areas

All the missionary areas are declared open to private sector participation (PSP) as promulgated in Republic Act 9136 known as the Electric Industry Reform Act, and DOE Department Circulars 2004-01-001 and 2019-0001. Through PSP, the government hopes to provide consumers in off-grid areas with opportunities and options for obtaining a reliable, environmentally benign, efficient and least-cost supply of power. A significant objective is to reduce public funding by allowing the inflow of private capital for power generation and electrification in off-grid areas, and to rationalize and ultimately comply with government efforts to remove the UCME subsidy.

Any of the following private entities can take over the function of the NPC as the generation company, through a competitive selection process (CSP):

- A Distribution utility (DU) or electric cooperative (EC) within its franchise area
- A New power provider (NPP), which is a private entity selected through competitive selection to provide power generation
- A Qualified third party (QTP), as an alternative service provider qualified and authorized to provide integrated power generation and distribution service

As of December 2020, there are 274 diesel power plants owned by NPC-SPUG open for privatization. Tidal energy developers can consider these power plants and explore if there is an opportunity to decarbonize the energy generation and improve the energy situation in these missionary areas by providing more sustainable energy solutions using tidal energy conversion systems.

II. A CASE STUDY OF TIDAL STREAM ENERGY DEVELOPMENT IN SAN ANTONIO, NORTHERN SAMAR

Local project developers Poseidon Renewable Energy Corporation and Oceantera Energy Corporation are jointly looking at developing an alternative energy solution to build capacity into or replace the existing diesel-based system in one of the off-grid areas, in San Antonio, Northern Samar. They are proposing to replace the existing diesel energy generation system with a renewable energy-based hybrid system using tidal and solar energy technology, combined with a suitable battery energy storage system (BESS). The system will be designed to provide sufficient generation to provide the local distribution utility with reliable power, 24/7 so that consumers have access to clean, reliable and consistent power. This is critical given that consumers are likely to adapt their livelihoods around this increase in reliability and availability; it is, therefore, essential that these adaptations are supported in a sustainable manner.

Working with Poseidon and Oceantera, the study conducted a case study of San Antonio through various means including site visits, data collection from the San Antonio Diesel Power Plant (DPP), Municipal Government of San Antonio, the distribution utility Northern Samar Electric Cooperative (NORSAMELCO), and household and business energy consumers on the island. As part of the case study, we carried out a high-level cost analysis of the proposed tidal energy conversion (TEC) hybrid energy system based on HOMER energy modelling. Using San Antonio as a case study, we aimed at the following specific objectives:

- Understand the current energy situation in island and coastal communities
- Compare cost structure of the existing diesel-based energy generation and the proposed TEC hybrid energy system
- Identify development strategy supporting the deployment of TEC systems in off-grid areas.

Overview of San Antonio

The Municipality of San Antonio is located in Dalupiri Island in Northern Samar in the Philippines (Figure 1). It is a remote island and only accessible by small outrigger boats. Its population is estimated to be 9,550 (51% male, 49% female) in which 2,435 (60% male, 40% female) are in intermediate, secondary and college education (San Antonio Municipal Planning and Development Office, MPDO 2019). Their sources of income are mainly fishing and farming but only approximately half of the population is actively engaged in economic activities. Of those who are no longer in school and do not have a source of living, about 39% are women.

A. Energy Situation in San Antonio

San Antonio represents the conditions of the missionary areas of the Philippines specifically the island and coastal communities. It is considered as one of the missionary areas and electricity is being supplied by a NPC-SPUG diesel power plant.

The NPC-SPUG San Antonio DPP is located in Barangay Ward III, San Antonio, Northern Samar, Philippines. It uses four (4) units of diesel generators to provide 24/7 electricity to the island. Table 1 summarizes the generator capacity, load, and energy generated based on the monthly operations report from 25 January to 25 February 2019 (NPC-SPUG, 2019). The DPP has a total installed capacity of 963kW and a net generation of approximately 100 MWh per month. The energy sales are recorded to be 95.70365 MWh.

Fig. 1. Location map of San Antonio, Dalupiri Island, Northern Samar

TABLE I. GENERATOR CAPACITY, LOAD, ENERGY GENERATED OF THE DIESEL GENERATORS IN SAN ANTONIO DPP

ID no	Make/ Model	Rated Capacity (MW)	Dependable Capacity (MW)	Peak Load (MW)	Min Load (MW)	Ave Load (MW)	Gross Generation (MWh)	Station Use (MWh)	Net Generation (MWh)
1	DALE-PERKINS	0.1630	0.1300	0.1000	0.0890	0.0801	1.089	0.009	1.07955
2	DALE-PERKINS	0.2500	0.2000	0.1430	0.0940	0.1043	7.343	0.063	7.27954
4	CUMMNS	0.3000	0.3000	0.2450	0.0930	0.1628	41.590	0.357	41.2330
5	CUMMNS	0.2500	0.2500	0.1660	0.0900	0.1226	50.334	0.432	49.90195
	Plant Total	**0.9630**	**0.8800**	**0.2450**	**0.0890**	**0.1350**	**100.356**	**0.862**	**99.49405**

The San Antonio DPP has an overall availability factor of 91% and a capacity factor of 14%. Individual running hours, shutdown hours, availability factor and capacity factor of each generator are presented in Table 2.

TABLE II. OPERATING HOURS, AVAILABILITY AND CAPACITY FACTORS OF THE DIESEL GENERATORS IN SAN ANTONIO DPP

ID **no**	**Make/Model**	**Operating Hours**	**Accumulated Running Hours**	**Reserved Shutdown Hours**	**Availability Factor (%)**	**Capacity Factor (%)**
1	DALE-PERKINS	13.59	44,883.89	730.41	79.75	0.90
2	DALE-PERKINS	70.39	47,789.76	673.61	80.00	3.95
4	CUMMNS	255.40	11,229.00	488.60	100.00	18.63
5	CUMMNS	410.60	4,872.79	333.40	100.00	27.06

The fuel consumption of the San Antonio DPP is around 32,100 liters per month. Fuel consumption and fuel rate of the individual generators are shown in Table 3.

TABLE III. FUEL CONSUMPTION AND FUEL RATE OF DIESEL GENERATORS IN SAN ANTONIO DPP

Unit no	**Make/Model**	**Fuel Consumption (Li)**	**Fuel Rate (Li/kWh)**			
			Gross	**Net**	**Gross***	**Net***
1	DALE-PERKINS	365	0.3352	0.3381	0.3673	0.3705
2	DALE-PERKINS	2,400	0.3269	0.3297	0.3412	0.3441
4	CUMMNS	12,945	0.3108	0.3135	0.3160	0.3187
5	CUMMNS	15,823	0.3144	0.3171	0.3187	0.3214
	Plant Total / Overall	**32,087****	**0.3140**	**0.3167**	**0.3197**	**0.3225**

*with and without generation

**including losses and other uses

Operating cost of the power plant totaled around USD 30,642 per month as presented in Table 4. Fuel cost constitutes more than 93% of the monthly operating cost. This is because of the high price of diesel, around USD 0.89 per liter, due to expensive transport of diesel to San Antonio.

TABLE IV. OPERATING COST OF THE SAN ANTONIO DPP

Item	**Cost (USD)**
Operation and maintenance (Manpower cost)	1,800.00
Fuel	28,600.00
Lube oil	241.50
Total plant operating cost, monthly	**30,641.50**

The fuel comes from another town called Tacloban City and is being transported by land to Port of Allen. The depot in Tacloban City is about 267-kilometer or 5-hour drive to Port of Allen. From port of Allen, the fuel is transported by the sea on outrigger boats to San Antonio. The delivery of fuel from the depot to San Antonio usually takes a day. Typically, 12,000 liters of diesel is delivered every 15th day of the month in which the logistics take almost a day.

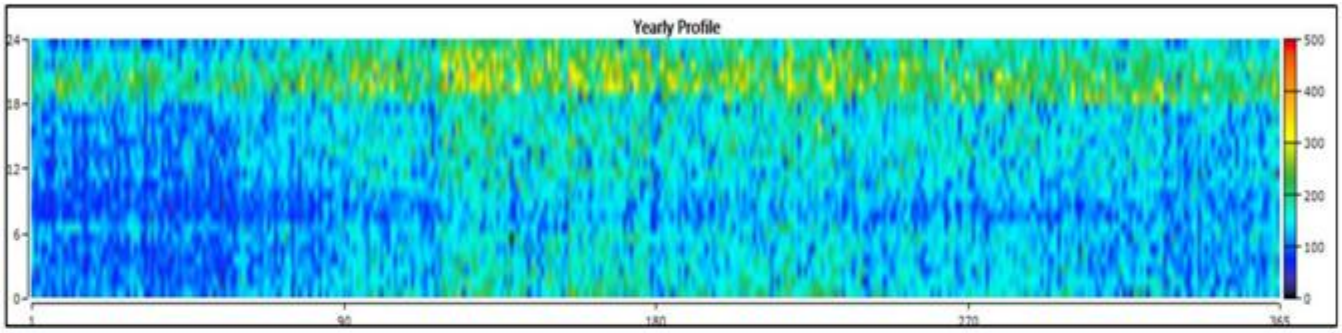
When there are weather disturbances like typhoons and sea travel is not safe, delivery of fuel to the island is hampered. This results in power interruptions, such as rotational brownouts. Also during this time of pandemic and lockdowns being implemented nationwide, the delivery of fuel to the island has become more challenging due to inter-town/inter-city travel regulations.

The electricity generated by the San Antonio DPP is bought and distributed by NORSAMELCO to the energy consumers of the island. NORSAMELCO collects USD 0.1128 per kWh from the consumers as the Subsidy Approved Power Rate (SAGR). With a True Cost of Generation Rate (TCGR) in San Antonio estimated to be USD 0.4968 per kWh the difference of USD 0.3840 per kWh is covered by the UCME subsidy. From the approximate energy sales, we calculated the UCME subsidy for San Antonio electricity generation to be USD 36,864 per month.

Proposed Tidal Energy Conversion Hybrid System (TECHS)

Oceantera carried out HOMER energy modelling to determine the initial design of their proposed renewable energy system. The concept of their energy solution is to integrate solar pv, tidal energy converter (TEC) and battery into the existing diesel generator (TEC hybrid system or TECHS).

They used the 2018 the hourly average energy dispatch of the San Antonio DPP taken from the days with normal operations (no power interruptions). From the analysis, the average energy daily consumption of San Antonio is 1,418,857 kWh per year (3887.28 kWh/day) with peak demand of 444.0 kW. Demand profile is shown in Figure 2.



Hr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	120.62	124.70	134.11	161.66	201.81	190.76	174.14	176.73	160.09	159.52	154.50	138.20
1	113.69	109.55	127.52	154.07	187.74	180.96	166.32	170.50	153.73	155.00	145.57	134.70
2	109.54	105.65	123.22	148.34	180.15	175.12	160.27	165.41	146.64	149.76	141.86	128.20
3	106.08	103.55	118.04	143.55	174.56	169.80	155.36	161.00	146.00	144.72	139.50	128.10
4	105.92	102.70	117.33	140.28	167.56	169.92	151.05	157.18	141.36	141.64	139.00	129.00
5	116.92	117.45	126.15	142.03	168.11	175.00	160.95	165.64	152.14	151.08	152.86	132.00
6	131.46	124.40	131.11	136.14	149.85	153.48	145.82	153.82	141.59	141.00	141.86	136.30
7	106.54	102.65	105.07	118.38	140.59	134.24	121.05	128.55	116.73	117.32	122.14	123.20
8	95.54	94.40	101.70	116.38	142.56	136.36	124.32	126.23	119.00	122.84	123.86	122.10
9	100.69	101.00	109.44	130.59	159.63	147.96	136.05	138.82	135.45	135.84	138.64	125.50
10	111.85	111.80	124.44	148.79	180.33	164.76	154.55	153.77	148.77	146.20	154.07	143.50
11	118.77	120.15	131.33	152.03	184.30	172.60	161.55	158.82	153.64	155.48	156.14	150.60
12	121.54	122.60	133.44	153.72	184.74	172.44	166.50	162.82	163.23	159.20	156.79	144.40
13	121.08	121.65	137.63	157.59	189.15	183.36	173.36	167.95	165.86	162.76	159.50	140.30
14	119.77	122.70	138.52	159.69	190.19	185.40	174.95	174.14	166.18	165.40	159.57	136.40
15	125.08	125.35	139.04	161.97	194.22	182.36	170.32	174.14	163.82	164.48	158.36	137.60
16	127.23	119.10	133.81	155.07	182.96	176.36	164.18	168.73	157.64	159.80	156.64	142.90
17	126.69	127.20	139.11	146.31	181.74	173.96	161.14	161.77	160.05	161.84	168.43	161.90
18	186.46	177.95	174.89	188.45	207.56	198.16	185.82	199.50	216.95	236.28	242.29	228.80
19	206.46	207.25	222.85	238.62	276.52	266.84	248.77	254.95	233.18	238.96	233.21	220.60
20	201.23	194.95	215.41	236.93	281.56	267.12	250.55	254.95	234.00	238.84	227.07	209.80
21	184.69	183.55	202.48	226.31	271.70	259.72	240.41	245.14	224.45	223.92	214.21	196.00
22	151.00	150.90	169.56	198.10	242.48	229.92	213.64	214.55	198.73	196.92	193.71	177.30
23	129.92	129.55	145.19	174.66	216.93	203.92	188.73	188.82	173.45	174.52	167.93	151.90

Fig. 2. The 2018 demand profile of San Antonio (in kWh)

Based on HOMER energy modelling, the TECHS has the optimized system architecture presented in Table 5 and Figure 3. It is proposed to acquire the two diesel gensets of the San Antonio DPP, and integrate 402 kWp solar pv, 1kWh lead acid type battery, and 420 kW TEC.

TABLE V. COMPONENTS OF THE TECHS

Component	Type	Size
Generator #1	CUMMNS 4 (Existing)	300 kW
Generator #2	CUMMNS 5 (Existing)	250 kW
PV	Flat plate PV	402 kW
Storage	Generic 1kWh Lead Acid	6 strings
System converter	System Converter	255 kW
Hydrokinetic	6 units x 70 kW turbine	420 kW
Dispatch strategy	HOMER Load Following	

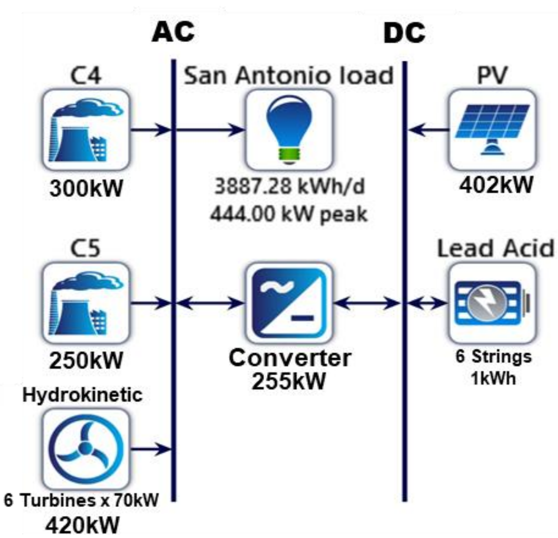


Fig. 3. Schematic diagram of the proposed TECHS

The energy modelling shows that the TECHS has an annual energy generation of 1,960,679 kWh and about 65% of the total production comes from renewable energy sources (Table 6).

TABLE VI. ELECTRICITY PRODUCTION OF THE TECHS

Component	Production (kWh/yr)	Percent
CUMMNS 4	79,326	4.05
CUMMNS 5	603,058	30.8
Flat plate PV	594,052	30.3
Hydrokinetic turbine	684,244	34.9
Total	1,960,679	100

Around 72% of its energy production is consumed (Table 7) meeting the energy demand of San Antonio and about 28% is unutilized (Table 8).

TABLE VII. ELECTRICITY CONSUMPTION OF THE TECHS

Component	Consumption (kWh/yr)	Percent
AC Primary Load	1,418,857	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	1,418,857	100

TABLE VIII. EXCESS ELECTRICITY AND UNMET DEMAND USING TECHS

Quantity	Value	Units
Excess Electricity	523,883	kWh/yr
Unmet Electric Load	0	kWh/yr
Capacity Shortage	0	kWh/yr

Based on the total fuel consumption (Table 9), the monthly average is calculated to be 17,394 liters. Since the monthly requirement for diesel is greatly reduced, the delivery of diesel to San Antonio can be scheduled only once a month. Having one delivery per month instead of two is an opportunity to reduce the cost of diesel.

TABLE IX. DIESEL CONSUMPTION OF THE TECHS

Quantity	Value	Units
Total fuel consumed	208,723	L
Average per day	572	L/day
Average per hour	23.8	L/hour

B. Cost Analysis of the Diesel Power Plant (DPP) and Tidal Energy Conversion (TEC) Hybrid System

Using the cost estimates for a diesel power plant provided by NPC-SPUG San Antonio DPP and the cost estimate for TECHS from Oceantera, we analyzed and compared the cost structure of a DPP and a TECHS in the context of San Antonio. Table 10 summarizes the general assumptions considered in the analysis.

TABLE X. GENERAL ASSUMPTIONS USED IN THE COST ANALYSIS

Item	DPP	TEC
Energy generation system	963 kW diesel generators (1 x 163 kW, 2 x 250 kW, 1 x 300 kW)	1,372 TECHS) 402 kWp solar pv, 1kWh lead acid type battery, 420 kW TEC, and 550 kW diesel gensets
CapEx	Based on expert judgment estimated at the current market price Included the following: - General module equipment cost - BOP equipment - Installation - General facilities and engineering	Based on suppliers' quotations, and expert judgment Included the following: - Acquisition of the existing diesel gensets - PV and inverter - Converter - Battery - Tidal energy converter (TEC) system - BOP equipment - Anchors and moorings - Marine operations - PV system integration - TEC system grid connection - General facilities and engineering
General OpEx	Manpower Diesel and other supplies Equipment O&M (including wear and tear)	Manpower Diesel and other supplies Equipment O&M (including wear and tear) Land lease
Refit maintenance	None	Inverter and battery scheduled in Year 12
Energy demand	1,418,857 kW/year	1,418,857 kW/year
Diesel consumption	494,704.45 L/year	208,723 L/year
Diesel price	~$1.06/L based on current diesel price including delivery cost at 2 deliveries per month	~30% lower due to reduction of frequency to once a month.
Project life	25 years	25 years
Discount rate	10%	10%

Table 11 presents the overview of the estimated capital expenditure (CapEx) and operating expenses (OpEx) of the DPP and the TECHS. CapEx of the TECHS is more than five times greater than the CapEx of DPP. The high CapEx of the TECHS can be attributed to its redundancy design to avoid the risk of power failure. This is the reason why the TECHS has a higher installed capacity (1,372 kW) compared to DPP (963 kW).

In terms of general OpEx per year, DPP is over twice more expensive to operate than TECHS. This is due to the cost of fuel which is estimated to be 91% of the total OpEx. It is important to note that in addition to the general OpEx, TECHS requires refit cost to replace the inverter and battery.

TABLE XI. CAPITAL EXPENDITURE (CAPEX) AND OPERATING EXPENSES (OPEX) OF DPP AND TECHS

	DPP	TECHS
CapEx	662,062.50	3,596,701.92
General OpEx per year	481,685.22	195,529.10
Refit in Year 12		50,100.00

To analyze the cost structure of DPP and TECHS, we calculated and compared the Present Value (PV) of the total project cost as shown in Figure 4. Considering the cost structure of DPP, it can be observed that DPP is significantly cheap to set up based on its CapEx. This is the main reason why the Philippine government prefers diesel-based energy generation in missionary areas over renewable energy systems. But the PV of its OpEx is substantially high.

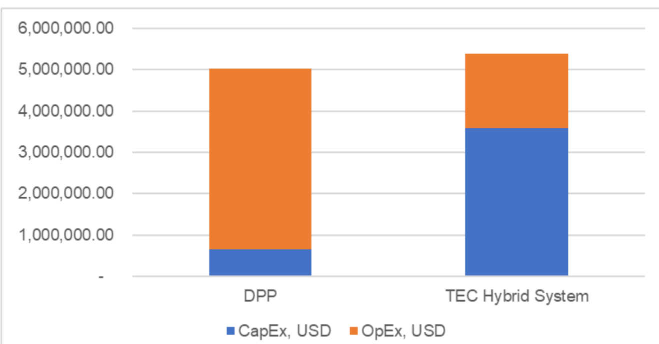


Fig. 4. Present value comparison of the total cost of TECHS and DPP

Considering the cost structure of the TECHS (in Figure 4), TECHS is capital intensive but once set up, the cost to maintain and operate it is minimal. It follows that the cost structure of low-carbon electricity generation is typically high in CapEx but low in OpEx (Hirth, 2016).

Comparing the total costs based on PV, Figure 4 shows that TECHS has slightly higher overall costs than DPP. Again, the main reason is that the TECHS has higher installed capacity (1,372 kW) compared to DPP (963 kW) due to the redundancy put in place for a more reliable source of power. Moreover, having diesel generators as part of the hybrid system, the cost of diesel contributed significantly to TECHS discounted OpEx.

It is important to note that the analysis assumes that there will be no changes on the diesel price which may not be the case. It is also observed that the cost of tidal energy converters is going down significantly in the last couple of years. Thus, the cost of TECHS will likely become more competitive with DPP.

Comparison of the Electricity Prices of DPP and TECHS

Using the assumptions in Table 11, we performed a high level financial analysis using a project internal rate of return (IRR) of 12%. We developed scenarios for DPP and TECHS determining the effect of diesel price vis-à-vis CapEx reduction of the TECHS on electricity price (Figure 5).

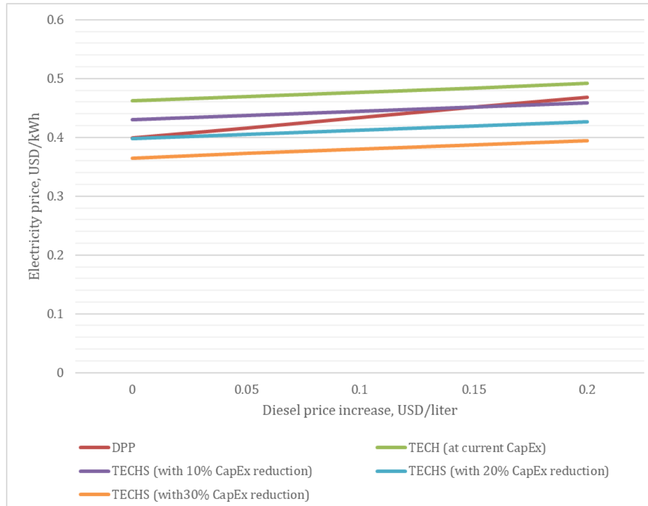


Fig. 5. Electricity price scenarios of DPP and TECHS considering increase in diesel prices and reduction in TECHS CapEx.

At the current diesel price and current TECHS CapEx, electricity price of DPP (~USD 0.40/kWh) is less expensive than the electricity price of TECHS (~USD 0.46/kWh). In this case, TECH would not be ideal to replace DPP as it will entail additional UCME subsidy and/or increase in SAGR collected from the island electricity consumers.

If TECHS CapEx goes down by 10 to 30%, TECHS becomes more competitive to and more attractive than DPP in terms of electricity prices. At 10% CapEx reduction, the electricity price of TECHS becomes comparable to DPP when diesel price starts to increase by USD 0.10 per liter and is projected to be lower as diesel price continues to climb. Electricity prices of TECHS are significantly lower than DPP if there is TECHS CapEx reduction of 20% to 30%.

III. CONCLUSIONS

The UCME program, developed to support missionary electrification, is based on the DPP cost structure. This is primarily because DPP requires low CAPEX investment, thus the government does not provide any upfront financial support to project developers in missionary areas. Thus the UCME subsidy is designed to support the costly OpEx inherent in DPP.

On one hand, the TECHS project developers may have to wait until diesel prices in the Philippines increase at a certain point and/or the TECHS CapEX goes down in the coming years brought about by technological advancements. On the other hand, TECH project developers may consider grant and other financial support mechanisms from various green financing institutions. Examples of the agencies offering grant funding and other financial support for this type of project are as follows: Blue Natural Capital Financing Facility (BNCFF); Energy Transition Partnership (ETP); Southeast Asia Clean Energy Facility (SEACEF); United Nations' Sustainable Blue Finance; USAID Energy Secure Philippines; UNDP's GEF Small Grants Programme; Green Climate Fund (GFC); Private Financing Advisory Network.

Grant funding that will reduce CapEx of TECHS by at least 20% will enable TECHS a more attractive option for providing clean and reliable energy in off-grid areas. This strategy will catalyze the development of tidal stream energy in the Philippines for decarbonizing the energy generation in Missionary Areas and increasing clean energy access of those communities in remote isolated islands.

At the moment, electricity from TECHS is still more expensive than diesel-based generation. This is primarily due to the initial CAPEX costs of TECHS. However, there is a potential that TECHS will soon be competitive with diesel. Nevertheless, the current study has shown that for a project targeting a missionary area, grant funding will be needed for its electricity price to be able to compete with DPP.

If the Philippine government is pushing for the development of renewable energy in off-grid areas, it may have to rethink the scheme of how financial support is being made available to power providers. The government must revisit its policies on the UCME subsidy, making it accessible as an upfront investment support to offset the large chunk of the capital costs of renewable energy, such as a TSE hybrid system.

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