Feasibility Study of Renewable Energy Using Levelized Cost Energy

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***Abstract*— Pulau Tioman used diesel to supply electricity to all residents. So, TNB comes out with a solution by implementing the renewable energy such as hydro and solar PV to supply electricity by replaced the usage of diesel. For this case study will be comparing the Levelized cost of using RE energy projects which used mini hydropower plant in Sungai Mentawak and solar PV for TNB Buildings with the existing diesel generators based on their expected energy (MWh/year) and expected savings (RM/year) and do some research on the cost of mini hydro power plant and solar for future expansion. Also, need to prove the calculation of LCOE using Microsoft EXCEL. The objectives of implement this renewable power plant were expected to reduce their operation cost and to increase penetration of renewable energy also introduce Smart Micro-Grid for long term sustainability.**

Keywords—renewable energy, non-renewable energy, levelized cost of energy, load profile, capital expenditures, operational expenditures

I. INTRODUCTION

As we all know Pulau Tioman is a very well- known island because of their tourist and attractions including their nature and wildlife habitat. Pulau Tioman is the biggest island on the east bank of Peninsular Malaysia. It is found at the co-ordinates 2" 35'N and 104" 15'E in the South China Sea. This island is found 32 km from Mersing. Johor and 80 km from Kuala Rompin (Pahang). Pulau Tioman can be accessed either by vessel from Tanjung Gemok, Kuala Rompin or Mersing. A few stream frameworks originating from the sloping forested territories speak to the primary supply of freshwater to the villagers. These streams are the tributaries of Sungai Mentawak [1]. Figure 1 and figure 2 below show the location of the project.

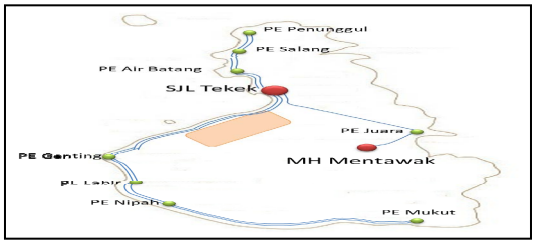

Fig 1: Mini Hydro Mentawak

Fig. 2: Tioman Island

Current by the electricity supply system in Pulau Tioman, are supplied through six diesel generators (500kW to 2400kW) ,with an installed capacity of 9.5 MW. Its derated capacity about 8.34kW and the maximum demand consumption of 4MW [2]. The cost of operating these diesel generators are very high. This is because they are not renewable energy and may lead to an unsustainable energy supply for the island. The challenges for this project are finding the list of cost for solar PV and hydro energy and compare with diesel, understanding the formula of Levelized cost of energy, also the cost of providing energy is higher than electricity tariff, hence utility is making a loss in providing electricity in Tioman Island and to find methods and ways to improve Levelized cost of energy. This case studies also need to achieve several objectives which are:

- To understand the topography of Pulau Tioman background
- To understand the concept of renewable energy (solar energy and hydro energy) and non- renewable energy (diesel)
- To learn more on Levelized cost of renewable energy based on their energy consumption
- Do a comparison between Levelized cost of solar energy and hydro energy with diesel
- Proved the calculation of Levelized cost of energy by using Microsoft EXCEL

First, renewable energy known as energy obtained from naturally repetitive and persistent streams of energy occurred in the local environment [3]. Renewable technologies

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considered as spotless wellsprings of energy and ideal utilization of these assets limit ecological effects, create the least optional squander and are feasible in light of present and future monetary and social societal needs. Renewable energy can be used to produce energy continuously, can be replenished and unharmed to nature.

Non-renewable source is, as its name recommends, an energy that originates from a source that can't be restored. The advantages of using non-renewable energy are high-end energy. This could be explained that non-renewable sources of energy such as coal and oil tend to give us more energy per unit than do renewable energy sources such as solar or wind energy. However, there could be disadvantages in using this non - renewable energy such that it can cause acid rains. When the fossil fuels burnt, it will release which causes rain to become acidic. This is very harmful to wildlife and also can cause damages to the buildings. It could affect humans' health because the non-renewable resources releases carbon monoxide and can cause respiratory problems if it goes into our systems. It still considered hazardous based on their colorless and odorless characteristics also not detectable by the human eye or smell. It also not feasible for future generation [4].

One of the renewable energy which is solar energy categorized into three groups which consist of Solar PV, Solar Heating and Concentrating Solar Power. Sun based photovoltaic (PV) frameworks specifically change over sun-based energy into electricity. The fundamental building square of a PV framework is the PV cell, which is a semiconductor gadget that believers sun based energy into direct current power. Advantages of using solar energy were conceivably boundless energy supply and causes no air or water contamination to the surrounding [5]. However, in solar system there still have their disadvantages which cost may not be effective.

Hydropower is a power from the energy of moving water. Flowing water makes energy that can be capture changed over into power by utilizing turbines. It is the flow of water in rivers, driven by the force of gravity to move from higher to lower elevations that can be used to generate hydropower [4]. Several benefits could be taken by using the Hydro Power Plant (HPP). It has low working and maintenance cost. It also one of the enduring and strong innovation; frameworks that can keep going for 50– 100 years or more without major investments. It is a dependable source of energy. For social aspects, HPP can enhance the way of life and could give flood protection. For environmental, it could provide a clean environment and no waste can be produced [6].

The cost analysis of renewable energy can be done by using a tool called LCOE. LCOE is a fundamental economic parameter that represents the cost per unit energy produced over the lifetime of a turbine or an energy farm for 20 years. The energy production (LCOE input) has been based on the power output of a reference turbine (or turbine farm), which is obtained from the rated power and the capacity and availability factors [7]. The LCOE is a helpful device since it can consolidate both the fixed expenses and variable expenses into a single measurement to improve analysis. An LCOE analysis can likewise enable firms to decide the advantages and downsides of different energy frameworks.

II. METHODOLOGY

In this methodology, the focus is on how to calculate LCOE using its formula based on the cost of the power produced by solar PV and mini-hydro over a period of time, typically the warrantied life of the system report the pre-calculation for the Levelized cost of energy for the project is calculated based on the data that have been collected. The data collected include the capital cost, operation cost, energy generated by mini-hydro, solar PV and compared it with diesel.

The data of Levelized cost of energy are collected from research on Preliminary Assessment on Sustainable Energy Utilization at Pulau Tioman by TNB Research and Status of Electricity Supply and Ongoing RE Projects in Pulau Tioman, Pahang by Tenaga Nasional Berhad [8].Pulau Tioman has variation in monthly electricity usage and mostly the diesel power plants are used diesel to generate electricity. The TNB Research team had done some research and decided to build two power plants using renewable energy which are solar PV and Mini Hydro because these two RE are very suitable for the condition of the place. Their main plans are to reduce the consumption of diesel because the amount of savings from not using diesel fuel can be up to RM 3 million in the first 5 years and up to RM 5 million in the last 5 years [2]. Figure 3, shows the maximum load demand from September 2016 to August 2017.

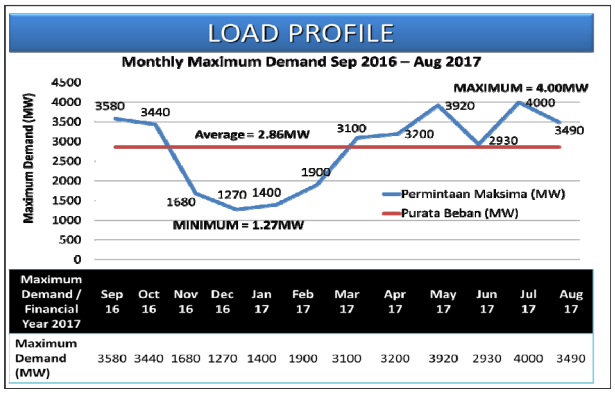

Fig. 3: Maximum Demand Load Profile In Tioman [9]

To get the value for LCOE, the simulation of load profile needs to be done by using HOMER simulation because LCOE calculation includes the net cost and the total of production cycle life of the turbine. HOMER simulation used to calculate load profiles for renewable energy [10]. The load profile in Pulau Tioman is calculated from October 2016 to August 2017 from 12:00 a.m to 12:00 p.m. The highest maximum demand is on July 2017 which is 4 MW [9]. As can be seen in the existing load profile, the wartsila generator is still running from 10: a.m to 11:p.m because it uses diesel. For solar,the load profile achieves to 69.95 kWh at 1 p.m because at that time, the weather tends to be very hot and sunny. It goes down to 0 kWh after 6 p.m when night appears and consistent on 0 kWh until the sun rises. For mini-hydro, it shows a consistent value of load profile because it only depends on tidal which suits with Pulau Tioman topography. The value of load profile can increase or decrease at certain time. This is because it depends on the

workloads at that time and weather. For example, from 9:00 a.m to 5:00 p.m are duration for working hours so people would use a lot of electricity and give a high value of load profile. The table below show the existing load profile and the hybrid load profile after installing more renewable energy.

The first method is LCOE can be calculated using manual calculation. Based on formula on equation 1 below,

$$LCOE = \frac{Net\ Cost}{Total\ Energy\ \frac{(kW)}{h} Produced\ Over\ Lifetime} \quad (1)$$

Where Net Cost = Total system cost deduct with taxes

Total Energy = Energy produced over life cycle time

1. High Operation Cost Of Diesel

The conventional generators are very costly as it has to do regular maintenance to ensure they always in good condition to operate. Table I below shows the operation cost for diesel [2].

TABLE I. DIESEL OPERATION COST

FY	2015	2016
Unit Generated (kWh)	12,617,007	12,940,133
Diesel Consumption (L)	4,043,885	4,280,695
Diesel Cost (RM)	8,087,770	8,561,390
Total OPEX Cost (RM)	14,473, 045	15,182,706
Cost per Unit (RM)	1.15	1.17

The high operating cost are due to the age of generator sets itself which around 17 to 24 years old, it also has a frequent breakdown, requires light maintenance and major overhaul and reducing in their efficiency.

TABLE II. DETAIL OPERATION COST OF DIESEL

FY	Cost (RM)
Variable fee (O&M)	RM 0.29 per kWh
Fixed Fee	RM 0.22 per kWh
Fuel Cost	RM 0.66 per kWh
Cost per Unit	RM 1.17 per kWh

Table II shows that the variable fee for the operation cost of diesel is RM0.29 per kWh which includes the operation and maintenance cost. The fixed fee is RM0.22 per kWh. The fuel cost is RM0.66 per kWh based on its formula in equation 2,

$$Fuel\ Cost = \frac{Total\ Diesel\ Cost}{Unit\ Generated} \quad (2)$$

The cost per unit stated in table II is RM 1.17 per kWh based on the formula in equation 3,

$$Cost\ Per\ Unit = \frac{Total\ OPEX}{Unit\ Generated} \quad (3)$$

Where, OPEX = Operational Expenditures

2. Levelized Cost Of Energy

TABLE III. LCOE FOR RENEWABLE ENERGY

RE	Solar PV	Mini Hydro
Total Energy Generated (kWh)	5,572,048	40,000,000
CAPEX (RM)	2,754,000	9,770,000
OPEX (RM)	692,735	8,900,000
Total Cost (RM)	3,446,735	18,670,000
LCOE (RM)	0.62	0.47

TABLE IV. LCOE FOR DIESEL

Non-RE	Diesel
Total Energy Generated (kWh)	12,940,133
CAPEX (RM)	14,720,000,000
OPEX (RM)	15,182,706
Total Cost (RM)	14,735,182,710
LCOE (RM)	1.14

Table III and Table IV show the value of LCOE for renewable energy and diesel. It shows the value of LCOE for renewable energy which is solar and mini-hydro is cheaper compared to LCOE for diesel. The capital expenditures refer to the amounts that will be used to buy major physical goods or services that will be used for more than one year. The capital expenditure includes the plant and equipment purchases, building expansion and improvement, all kinds of hardware purchases and vehicles to transport goods. Operational expenditures refer to the costs for them to run a business like pay for the rent of certain places, utilities, for research and development also the operation cost of diesel.

For renewable energy such as mini-hydro and solar PV not requires regular maintenance as they are capable to withstand within years and can operate in a long time. They are cheaper because their capital expenditure and operational expenditures cheaper compared to diesel. Also, renewable energy much cleaner than diesel. Figure 4 below shows the installation of solar in Tioman Island.

Fig. 4: Solar PV

III. ANALYSIS AND DISCUSSION

The load profile as in Table V is simulated using a software name HOMER Pro Microgrid. HOMER software

is used to simulate load profile for renewable energy. For LCOE, the manual calculation has been done for both solar PV and mini-hydro.

1. Existing Load Profile System

TABLE V. EXISTNG LOAD PROFILE

Load profile		Generation Unit Commitment		
Time	Load (kW)	Time	Solar	Mini Hydro
0	1067.28	0	0	278.1
1	2066.57	1	0	344.53
2	995.47	2	0	224.72
3	1072.16	3	0	224.8
4	1154.86	4	0	250
5	860.41	5	0	221.03
6	1026.75	6	0	230.32
7	3093	7	6.54	300
8	2016.8	8	25.94	250
9	2729.84	9	42.97	320
10	7295.25	10	38.81	350
11	6268.43	11	62.06	350
12	6972.02	12	53.11	350
13	6579.45	13	69.95	350
14	5455.4	14	59.55	250
15	6683.85	15	56.19	250
16	8980.5	16	40.6	400
17	5627.62	17	25.35	250
18	3624.52	18	9.82	0
19	3293.44	19	0	0
20	5786.48	20	0	250
21	3515.27	21	0	0
22	3632.85	22	0	350
23	937.08	23	0	350

2. LCOE For Existing System

TABLE VI. LCOE EXISTING SYSTEM

Types Of Genset	Solar	Mini Hydro
Total Load (Daily) kWh	490	6,143.5
Total Load (Monthly) kWh	15,217	190,448
Total Load (Yearly) kWh	182,611	2,285,382
Total Load (20 years) kWh	3,652,221	45,707,640
Net Cost	3,446,735	18,670,000
Lifetime Cycle	20 years	20 years
LCOE	RM0.94/ kWh	RM0.40/ kWh

Table V and Table VI above show the existing load profile for renewable energy and LCOE for the existing system [20].

The calculation for LCOE have been done based on the LCOE formula in equation 1,

Where $$LCOE = \frac{Net\ Cost}{Total\ Energy\ (\frac{kW}{h})Produced\ Over\ Lifetime} \quad (1)$$

3. Hybrid Load Profile

For hybrid load profile also simulated by using HOMER software and previously, in the existing system have two renewable energy and for the hybrid system, wind energy is proposed. This is because the wind is one of the suitable renewable energy that can be implemented as the place can get very windy at a certain time. The hybrid system can get enough energy from both sources and even if the energy from one source is low, it will be compensated by the other.

TABLE VII. HYBRID LOAD PROFILE

Load Profile		Generation Unit Commitment			
Time	Load (kW)	Time	Wind	Solar	Mini Hydro
0	491.29	0	0	0	122
1	951.28	1	0	0	0
2	458.23	2	24.46	0	142
3	493.53	3	25.15	0	178
4	531.06	4	55.49	0	181.3
5	396.06	5	34.02	0	159
6	472.63	6	22.82	0	186
7	1423.76	7	14.01	49.67	237.2
8	928.37	8	24.2	273.26	222.4
9	1256.59	9	42.85	451.92	193
10	3358.13	10	55.07	430.46	397

11	2885.47	11	28.83	659.58	182.5
12	2885.47	12	3.27	581.68	201.2
13	3028.64	13	0	739.48	194.05
14	2511.21	14	0	639.71	278
15	3076.69	15	0	596.09	222
16	4133.38	16	0	535.09	400
17	2590.49	17	0	270.41	220
18	1668.43	18	9.29	100	137
19	1516.03	19	0	0	0
20	2663.62	20	3.07	0	0
21	1618.14	21	1.32	0	0
22	1211.95	22	1.11	0	0
23	447.92	23	0	0	225.6

TABLE VIII. LCOE HYBRID SYSTEM

Types Of Genset	Solar	Mini Hydro	Wind
Total Load (Daily) kWh	5,220.35	4,078.25	344.96
Total Load (Monthly) kWh	161,830.85	126,425.75	10,693.76
Total Load (Yearly) kWh	1,941,970.20	1,517,109	128,325.12
Total Load (20 years) kWh	38,839,404	30,342,180	2,566,502.40
Net Cost	3,446,735	18,670,000	4,398,240
Lifetime Cycle	20 years	20 years	20 years
LCOE	RM0.08 /kwh	RM0.08 /kwh	RM1.71/ kwh

Table VIII shows the value of LCOE for three renewable energy and it shows that the LCOE cost is more cheaper compared to the existing system and diesel.

For wind energy, the LCOE showed a high value compared to solar PV and mini-hydro. This is because the cost of wind energy installation is slightly higher compared to these two renewable energy. The high cost of CAPEX and OPEX can affect the LCOE cost. For the future plan, wind energy can be implemented as it can be a backup source of electricity if the two renewable energy resources not enough to supply electricity.

IV. CONCLUSION

Based on the results and discussion, the most suitable renewable energy resources that can implement in Tioman are solar energy and mini-hydro compared to wind and diesel. From the results that have been taken, although the value of LCOE for renewable energy showed a higher value compared to existing which includes more diesel, renewable energy can save more cost for a longer time compared to diesel. This is because the diesel needs to do maintenance frequently and they depend on the ageing of generator sets. From the LCOE values also, we can see the LCOE for solar and mini-hydro is cheaper compared to wind and diesel. Moreover, wind turbine tends to produce noise and visual pollution compared to solar and mini hydro. Besides that, wind energy required a large windy area as wind not always blowing [11]. There also differences before and after installation of RE. Although LCOE of RE showed a higher value of cost compared to diesel, it can reduce the utility cost and their equipment can last longer than diesel generators. RE technologies are clean and they do not need frequent maintenance which reduces the workloads of workers. Installations of RE also can give more profits to TNB compared to the use of diesel generators which cause big losses to the company.

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