COST ESTIMATION OF A STANDALONE PHOTOVOLTAIC POWER SYSTEM IN REMOTE AREAS OF SARAWAK, MALAYSIA

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ABSTRACT

This paper aims to estimate the anticipated costs incurred from a standalone solar photovoltaic power system for the supply of electricity to the rural community in Sarawak, Malaysia. The life cycle cost analysis with net present value technique was employed for the evaluation of cost system. It was found that purchasing of solar photovoltaic components and the system installation cost will contribute 63% of the total investment and future anticipated costs will add to the remaining. Recurring cost will make 25% and components replacements 75% of future anticipated costs. It was discovered that the power generated from the solar photovoltaic system would be 38 times more expensive than electricity produced from the conventional sources. However, its installation in remote areas could be favourable where the grid-connected power supply is not accessible.

Keywords: economic analysis; life cycle cost; net present value; solar photovoltaic system.

1. INTRODUCTION

The cost of energy produced by solar photovoltaic power systems has dropped significantly since 1980. However, its expenses are still higher than conventional power sources such as oil, gas, coal, hydro etc due to high initial costs . Photovoltaic (PV) projects outweigh the low initial cost of conventional powers systems especially due to their low operating and maintenance costs. Solar PV systems are durable, environmental friendly, easily accessible and have no need of labour and fuel for their operation [2, 3]. It is desired to properly estimate the future anticipated costs of solar PV systems, because it has many design variables which affect the overall project cost. The system performance is much more sensitive to the effective panel area which is primary design variable than to any other variable because of its high purchasing cost. However, this difficulty is often

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resolved by determining the size of a solar energy system for a known load, with a storage capacity and other parameters fixed in relation to panel area . The desirable prediction of incurring costs can only be made by the detailed and comprehensive study of various types of costs, quantification of economic factors that influencing the system expenses, and comparing the merits and drawbacks of different tools and measures.

2. BACKGROUND OF COST SYSTEM

Typically, there are two different types of costs are anticipated from solar PV system, namely capital costs and future costs. Capital costs are acquisition costs incur prior to the occupation of the facility including the purchasing cost of each component of the system and installation cost of the project. Approximately 60 to 80% of system life cycle cost is locked in this phase. Failure to understand the system operation can significantly affect the future maintenance and replacement costs . Future costs can be classified as two parts, such as recurring and non-recurring costs. Recurring costs occur every year over the span of study period for example the maintenance, repair and operation costs. Maintenance costs (M_c) are planned costs to keep the PV system in good condition by deliberate inspections. Repair costs are unforeseen, and very difficult to predict when they will occur. For simplicity, the maintenance and repair costs are treated as annual costs. There is no absolute standard as to which costs are included in maintenance costs, however, they can be broken into the various categories. Those costs that occur only when the system is operating are known as variable and those which do not vary with the output of the system but rather required to keep the system in smooth operating condition are termed as fixed. Energy costs are typically variable, whereas the labour costs are frequently fixed. For mature conventional systems, the annual M_c is considered to be about 1% to 2% of the system's initial capital cost . Non-recurring costs are known as onetime costs, because they do not takes place every year over the span of study period. These include replacement of major components, major system repair and maintenance tasks. These are predictable expenditures that are required to maintain the operation of a facility .

2.1 Economic Factors

The major economic factors required for economic appraisal are life cycle length of system, inflation rate and discount rate. The length of the analysis period is chosen to be the best service life of the longest-living component. Inflation rate refers to a general rise in prices measured against a standard level of purchasing power. Typical annual inflation rates for remote power systems are 5 to10 % for fuel and 3 to 8 % for non-fuel expenses . The inflation rate in Malaysia was last reported at 1.90% in July of 2010. From 2005 until 2010, the average inflation rate in Malaysia was 2.77% reaching an historical high of 8.5% in July of 2008 and a record low of minus 2.4% in July of 2009. Costs and revenues can be expressed either in current dollars or constant dollars. Actual cash flows observed in the marketplace are called current dollar cash flows (F_m). Their values will change over time because of inflation or deflation. Constant dollar cash flows (F_n) represent the number of dollars that would have been required if the cost was paid in the base year (n). Cash flows expressed in current dollars in year m (F_m) can be transformed into constant dollar cash flows in any year n, (F_n) by removing the effect of inflation (e) in the following equation.

$$F_n = \frac{F_m}{(1+e)^{m-n}} \tag{1}$$

Eq. (1) assumes a constant inflation rate during the m-n years.

The discount rate is defined as a rate of interest reflecting the investor's time value of money. Time value is the price put on the time that an investor waits for a return on an investment. The discount rate is basically equivalent to the amount of money that could make the capital if it is chosen for an investment in a bank or other savings program rather than in a power system. Typical values of discount rate ranges from 7 to 15 percent. The 19 year average real interest rate in Malaysia from 1987-2005 was 4.84%. Its rate from 2004 to 2010 was recorded as 2.91%. Maximum real interest rate was found 10.3% in 2001 and minimum was reported minus 0.17% in 2004. The discount rates have two types, real and nominal. Real discount rate excludes the rate of inflation, whereas the nominal discount rate includes the rate of inflation. The use of either discount rate in its corresponding present value calculation derives same result. However, the discount rates can also be converted from real to nominal or vice versa by incorporating the inflation or deflation rates using the following formula [8, 9].

$$d_r = \frac{1+d_n}{(1+e)} - 1 \tag{2}$$

2.2 Economic Measures for Cost Estimation of PV Systems

The selection of economic measures is determined by several factors, that include the investor's perception, regulation, risk, financing, cash flow, comparison of mutually exclusive alternatives, similarity of alternatives benefits, and size and purpose of investment. The cost-effective alternatives are those with the lowest total life cycle cost (TLCC), revenue requirements (RR), levelized cost of energy (LCOE), simple payback (SPB) and depreciated payback (DPB), and the highest net present value (NPV), internal rate of return (IRR), modified internal rate of return (MIRR), benefit to cost ratio (B/C) and savings to investment ratio (SIR) as given in **Table 1**. Different measures may not always provide the same answer when comparing alternatives. For example, SPB approach rejects an alternative that have a longer payback period, though it shows high long-term returns.

Table 1. Overview of economic measures applying to social investment features and decisions

Decisions on Investment	NPV	TLCC	RR	LCOE	IRR	MIRR	SPB	DPB	B/C	SIR
Risk Analysis	A	A	A	A	A	A	C, P	P	A	A
Combinations of Investment	A	A	A	A	A	A	A	A	A	A
Accept or Reject	A	NR	NR	A	C	A	A	A	A	A
Selection from mutually exclusive alternatives	P	C	A	NR	NR	NR	NR	NR	NR	NR
Ranking/ limited budget	A	A	A	P	C	P	NR	NR	P	P

A = Acceptable; C = Common; P = Possible; NR = Not Recommended

2.3 Life-Cycle Cost (LCC)

Life cycle cost is the sum of all the costs associated with an energy delivery system over its lifetime or over a selected period of analysis in today's dollars. It discounts the all expected costs to their present value and takes into account the time value of money [12, 13]. It is also an important tool for ranking the cost of ownership between mutually exclusive alternatives . Additionally, the future costs are adjusted to present value by applying the discount rate over the period between the present and the time when the cost will be incurred. Same discount rates are applicable for the comparison of alternative projects in a given period. If the real discount rate is used in present value calculations then the cost should be expressed in constant dollars. The analysis will be flawed when the cash flows are not discounted by using appropriate rates. Inaccurate predictions and false assumptions regarding the future costs may result wrong decisions and consequently leads to the project failure. The output from a LCC analysis is only depends on the values of good inputs. It is not recommended for the economic evaluation of approval or refusal of any investment. The overview of economic measures is summarized in **Table 1,** and their merits and limitations are given in **Table 2.** Larson [17] used a simple model for the calculation of life cycle cost (LLC) is expressed as.

$$LCC = \frac{(C + M + R) - S}{E} \tag{3}$$

where C is capital cost, M is maintenance and repair cost, R is replacement cost of system components and S is salvage value of the project residuals, and E is the energy produced by the system (kWh). Larson (1992) model is selected for this analysis with small modifications as it is a suitable model and easy to understand. It also relates the equation with the energy output from the system. A term introduced in Eq. (3) for incorporation of environmental protection and disposal costs projected from the proposed project. The modified form of proposed LCC formula used for this evaluation is expressed as

$$LCC = \frac{(I_{pc} + I_c + M_c + R_c + P_c) - R_v}{E} \tag{4}$$

The civil work and installation costs were taken as 40% of PV generator price for PV part. The present value of M_c for life time of hybrid system was assumed to be 1% of the initial cost for PV generator and inverter. For battery storage and other components, the annual maintenance cost was considered as zero. The batteries in the system will require inspection and topping up, approximately every 3 to 6 months. It is assumed that the batteries require little maintenance and care from time to time. For that purpose, M_c is assumed to be 1.5% of purchasing cost. The present value of system component replacement cost is the present value of all the replacement costs occurring throughout the system lifetime. In this study, the battery, controller and the inverter need to be replaced periodically during the system lifetime. The other system components are assumed to have the system life. The disposal cost of discarded materials and environmental protection costs and recovery

Table 2. Merits and limitations of main economic tools for calculation of LCC

Economic Tools	Merits	Limitations	Comments
Net Present Value (NPV)	Takes the time value of money into account. Generates the return equal to the market rate of interest [24, 25].	Not usable when the comparing alternatives have different life length. Not easy to interpret [23].	Most LCC models utilize the NPV method [23]. Not usable if the alternatives have different life length [24].
Simple Payback (SPB)	Easily calculated and interpreted [24].	Does not take inflation interest or cash flow into account.	Rough estimation if the investment is profitable [24].
Discount Payback Method (DPB)	Taking the time value of money [24].	Ignores all cash flow outside the payback period [24].	Only useful for screening but not decision making [24].
Equivalent Annual Cost (ECA)	Different alternatives with different life length can be compared [26].	Gives a mean value & doesn't specify the actual cost during each year of the LCC [26].	Comparing different alternatives with different life's length [26].
Internal Rate Of Return (IRR)	Results are presented in percent which gives an obvious interpretation [24].	Calculations need a trial and error procedure. Determined when the investments will generate an income [24].	Can only be used if the investments will generate an income [23].
Net Savings (NS)	Investment can be easily decided and [23].	Can be used if the investment generates an income [23].	Can be used to compare investment options, if the investment generates an income [23, 26].

and reuse value from the system are varied from case to case. Both disposal cost and salvage value (R_v) are future cost and often difficult to estimate . Environmental protection and disposal cost (P_c) may be taken from 3% to 20% of initial purchasing cost. R_v is a net value of a system at the end of life cycle cost analysis period. It is the only costs of LCC analysis, which is acceptable because it minimize the system cost. All types of projected costs either maintenance, repair, operation, replacements and residual value are required to be discounted to their present value then the costs can be summed to generate LCC of the project.

2.4 Calculation of Net Present Value of LCC

For fixed amount of money to be paid in *n* years, the present value interest factor (I_F) and the present value (P_v) of non-recurring costs (used for replacement costs) is calculated as by Eqs. (5)-(7) [15, 20].

$$I_F = \frac{1}{(1+d)^n} \tag{5}$$

$$P_v = F_n \times I_F \tag{6}$$

Therefore

$$P_v = \frac{F_n}{(1+d)^n} \tag{7}$$

For annual recurrent expenditure, the present value of interest factor annuity (I_{FA}) and P_v for every future year's cash flows are calculated separately when the each future year's cash flow is uneven or differs in amount. Eqs. (8)-(10) can be used for the determination of I_{FA} and P_v by the sum of all individual years' cash flows.

$$I_{FA} = \sum_{1}^{n} \frac{1}{(1+d)^n} \tag{8}$$

$$P_v = \sum_{1}^{n} \frac{F_n}{(1+d)^n} \tag{9}$$

$$P_v = \frac{F_1}{(1+d)^1} + \frac{F_2}{(1+d)^2} + \frac{F_3}{(1+d)^3} + \ldots\ldots + \frac{F_n}{(1+d)^n} \tag{10}$$

If the annual recurrent expenditure or future expenditures (cash flows) are fixed in size and regularly occur over a specific number of periods, the situation is known as an annuity. Then, the I_{FA} and P_v of costs is given by Eqs. (11)-(13)

$$I_{FA} = \frac{(1+d)^n - 1}{d(1+d)^n} \tag{11}$$

$$P_v = F_n \times I_{FA} \tag{12}$$

$$P_v = F_n \frac{(1+d)^n - 1}{d(1+d)^n} \tag{13}$$

3. METHODOLOGY

The cost per kWh of energy produced by a standalone PV system for the supply of electricity to a typical household at Kuching was calculated by using the actual solar irradiation and ambient temperature data obtained from Malaysian Meteorological Department Regional Office Kuching. The LCC method with NPV as an estimated tool was applied for this analysis because of its numerous advantages over other economic measures based on comparative study of different cost methods as described in **Table 1** and **Table 2**. Sarawak region is located in the tropical zone and receive too much rainfall with dense forests. The large portion of rural community are living in villages, which are located far from the power transmission lines and deprived of basic electric needs. It was assumed that there is no transmission grid to supply electricity to the rural community, and other power generation sources are not adaptable due to the geographical conditions, transportation problem, and other difficulties.

Table 3. Life Cycle Cost Analysis of a Standalone Photovoltaic System

Categories of Cost	Breakup of Cost Parameters/Items	Year (a)	Cost (US$) (b)	I_F (c)	I_{FA} (d)	Present Value (P_V) (US$)
Capital Cost (Acquisition Cost)	(a) Purchasing of Equipment costs					
	PV Modules	0	29300.00	1		29300.00
	Controller	0	1899.54	1		1899.54
	Batteries	0	9425.00	1		9425.00
	Inverter	0	2919.84	1		2919.84
	(b) Installation Cost					
	Structure, cables and wires, and labor cost (40% of Purchasing cost)	0	17417.75	1		17417.75
Future Cost	(a) Recurring Expenses					
	Operation and Maintenance Cost (1.5% of Purchasing Cost)	1 to 25	653.20		14.094	9206.20
	(b) Non-recurring Expenses (Replacement Costs)					
	(i) Battery Bank	5	9425.00	0.7835		7384.49
		10	9425.00	0.6139		5786.01
		15	9425.00	0.4810		4533.43
		20	9425.00	0.3769		3552.28
	(ii) Controller	8	1899.54	0.6768		1284.00
		16	1899.54	0.4581		870.00
	(iii) Inverter	8	2919.84	0.6768		1975.05
		16	2919.84	0.4581		1337.58
	(c) Pollution Mitigation/ Disposal cost	25	1306.77	0.2953		385.76
Salvage Value			870.9	0.2953		257.18
LCC (NPV)				=	97019.75 (US$)	
Annuity = LCC (NPV)/I_{FA}				=	6883.76 (US$)	
Net Cost/kWh = Annuity/E				=	4.72 (US$/kWh)	

A PV module with a rated power of 215 W and efficiency of 14.48% was considered for this analysis. The efficiency of other components such as charge controller, battery bank, inverter and the losses the distribution system were assumed as 95%, 85% , 90% and 2% respectively. The length of the analysis period was chosen to be the best service life of the longest-living component, i.e. the PV modules with a lifetime of 25 years. The life span of controller, inverter and battery were assumed to be 8, 8 and 5 years and their needs replacement of 2, 2 and 4 times respectively. The real discount rate was taken as 5% on the basis of 20 years analysis of Malaysian economy. The cost of system installation, annual maintenance, pollution mitigation and recycle value of scrap material was assumed to be 40%, 1.5%, 3% and 2% of the purchasing cost of the system components respectively. The tilt angle was taken as the latitude of location. The energy produced by the proposed PV system was determined to be 1460 kWh/year. The categories and breakdown of life cycle cost analysis with projected future costs are presented in **Table 3**.

4. RESULTS AND DISCUSSION

It was found that the capital cost makes up 62.6% and anticipated future costs shares 37.4% of all expenses, with an amount of US$60962.13 and US$36315.00 as shown in **Table 3** and **Figures 1** and **2,** respectively. The percentage share of capital investment and future anticipated cost

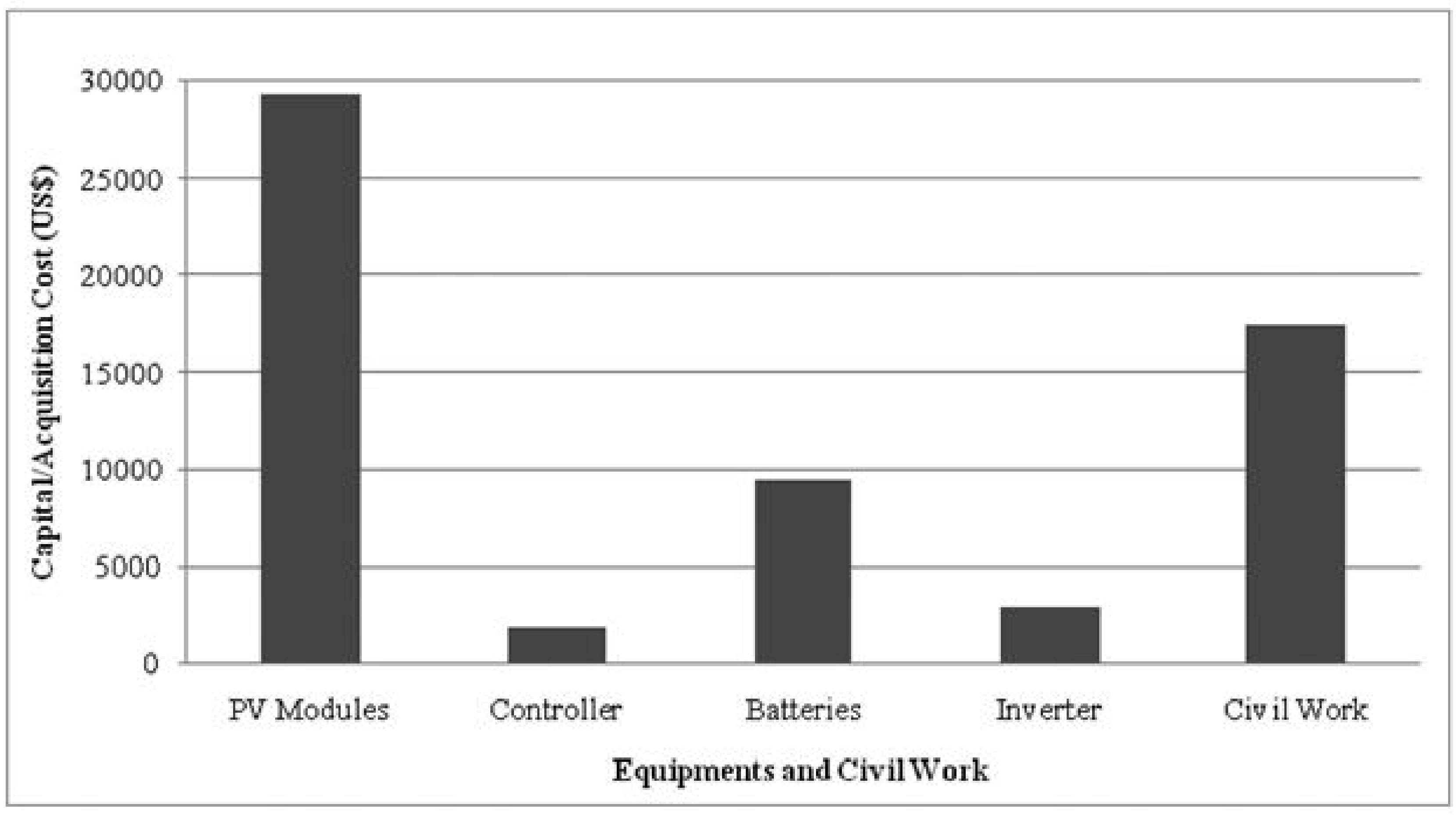

Figure 1. Purchasing and installation cost of PV system components.

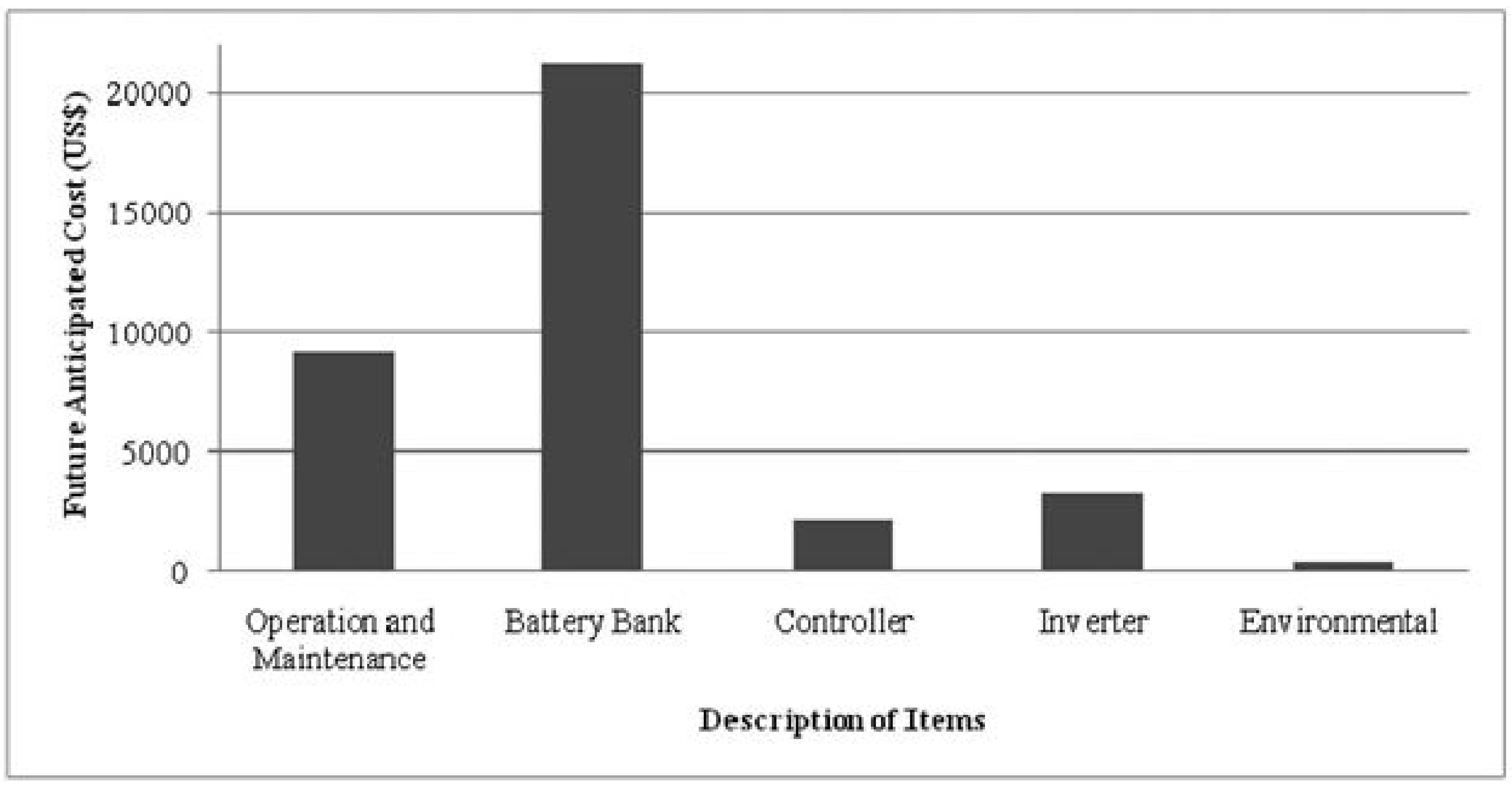

Figure 2. Future expected cost of different PV system components.

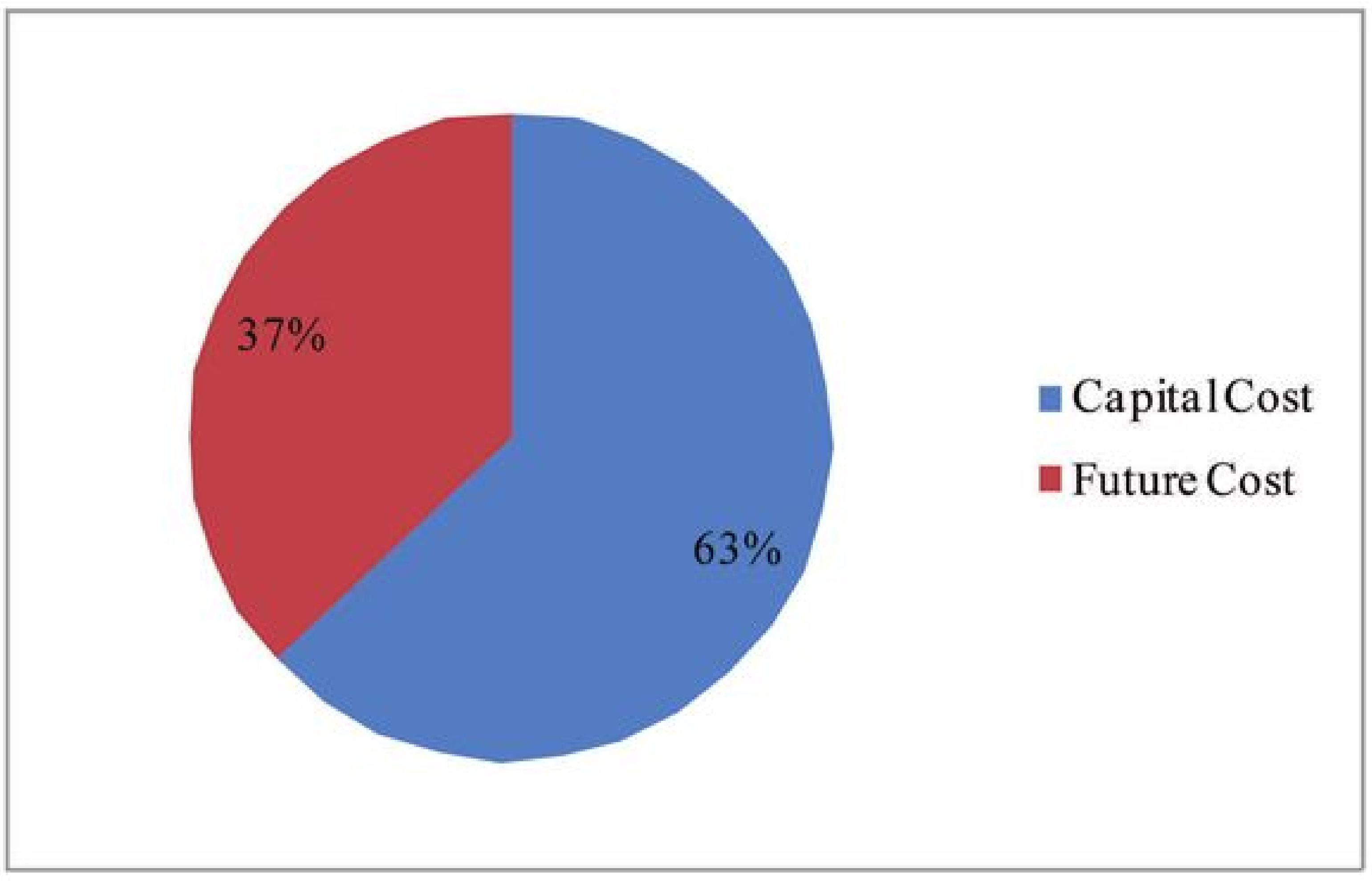

Fig. 3. Share of Capital Investment and Estimated Future Cost of PV System.

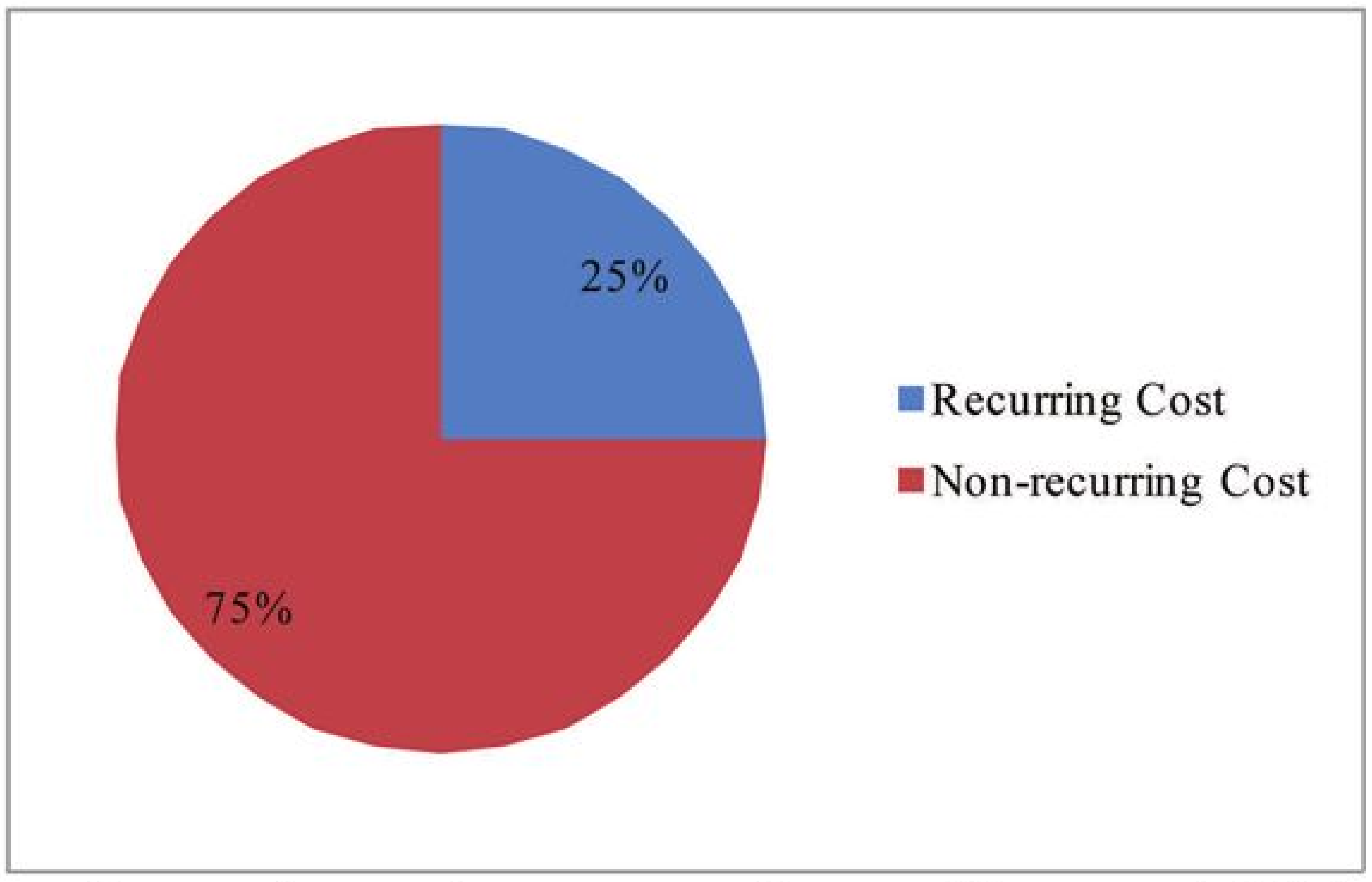

Figure 4 Share of recurring and non-recurring cost in expected future cost of PV system.

is shown in **Figure 3**. The percentage contribution of recurring (operation and maintenance) and non-recurring (replacement of components) of future anticipated cost is given in **Figure 4**. The total lifetime expenses were US$97276.93 and benefits from the reuse and recovered value was expected to be US$257.18. The total electricity was produced by the plant was found 1460 kWh/year or 4 kWh/day. The total life time cost was estimated to be US$97019.75 with annual average cost of US$6883.76.

The energy cost generated from the Standalone PV system is projected to be US$4.72/kWh. The estimated cost from the system is reasonable when compared to other places of Malaysia and European countries. The energy cost determined at Ipoh, Perak, Malaysia was US$1.75/kWh [27]. In Malta, the estimated energy cost was US$ 2.44/kWh [14]. The predicted levelized energy cost for a standalone system was ranges from US$1.039/kWh at lower Mediterranean countries to US$8.177/kWh in northern European countries. In this study, the cost per kWh was found within acceptable range.

At present, the average electricity tariff for industries and commercial purposes in Malaysia is at US$0.125/kWh. The present tariff of energy in Malaysia is 38 times lower than anticipated costs incurred from PV system. From 2005 until 2010, the average inflation rate in Malaysia was 2.77 percent. Due to the inflation rate the prices of conventional power generation units become increase in future. Since, the PV system prices continued to decline from the last decades and become viable in future, otherwise it is an expensive alternative. The results revealed that the PV system is a costly investment for generation of electricity as compared to the non-renewable energy sources, although it brings about numerous other benefits to environment as a whole.

5. CONCLUSIONS

It was exposed from the results that the capital cost from the installation of the PV system in remote areas of Sarawak, Malaysia will contribute 63% and future anticipated expenses will share 37% of total investment. Recurring cost from the project will be about 25.4% while the replacement of components will add 74.6% of future costs. The expected annual cost from this scheme was estimated to be US$6883.76 with yearly energy output of 1460 kWh. The projected costs incurred from PV system per kWh would be 38 times higher than present electricity tariff in Malaysia for industrial and commercial purposes.

Following conclusions may be drawn from this study.

1. The standalone PV power generation system is an expensive alternative for the generation of electricity as compared to conventional sources of energy, even though it is favourable for the environment.

2. The development of standalone PV systems in remote areas could be preferred with the combination of other power producing units or where the electrical transmission lines are expensive to build for the supply of electricity.

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NOTATIONS

d discount rate (either real or nominal, should be consistent throughout the project analysis)
d_n nominal discount rate
d_r real discount rate
e inflation rate
F_m constant dollar cash flows (US$)
F_n current dollar cash flows (US$)
I_c installation cost including civil work (US$)
I_F interest factor
I_{FA} interest factor annuity
I_{pc} initial purchasing cost of all system components (US$)
M_c operation and maintenance cost (US$)
M current dollars in m (any year of analysis)
n constant dollars in year n (base year of analysis)
P_v present value of anticipated costs (US$)
R_c replacement cost of all system components (US$)
R_v salvage (reuse, recovery and recycle) value (US$)

REFERENCES

[1] Khatib T. A Review of Designing, Installing and Evaluating Standalone Photovoltaic Power Systems. J App Sci 2010;10(13):1212-1228.

[2] Offiong A. Assessing the Economic and Environmental Prospects of Stand-By Solar Powered Systems in Nigeria. J App Sci Envir Mgt (JASEM) 2003;7(1):37-42.

[3] Mahrane A, Chikh M, Chikouche A. Energy Management for Stand Alone PV System. Jordan J of Mech and Ind Eng 2010;4(1):117-120.

[4] Duffiee JA, Backman WA. Solar engineering of thermal processes. John Wiley & Sons Inc, Hoboken, New Jersey 2006. p. 747-775.

[5] Bhuiyan MMH, Ali AM, Mazumder RK, Hussain M. Economic Evaluation of a Stand-alone Residential Photovoltaic Power System in Bangladesh. Renewable Energy 2000;21:403-410.

[6] Klein J, Rhyne I, Bender S, Jones M. Comparative Costs of California Central Station Electricity Generation. California Energy Commission, USA, 2009. p. 1-68.

[7] Ellis BA. Life Cycle Cost, The Jethro Project Report, 2007 (accessed on 17 June 2011). Available from http://www.jethroproject.com /Life%20Cycle%20Cost1.

[8] Short W, Packey D J, Holt T. A Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies. National Renewable Energy Laboratories, USA, 1995. p. 1-69.

[9] Mearig T, Coffee N, Morgan M. Life Cycle Cost Analysis Handbook. State of Alaska - Department of Education & Early Development, 1st Edition, Education Support Services-Facilities, 1999. p. 1-28.

[10] Malaysia National Statistical Data; (accessed on 17 June 2011). Available from http://www.tradingeconomics.com/malaysia/indicators, & Economy Statistics- Real Interest Rates Malaysia, Historical Data; (accessed on 17 June 2011). Available from http://www.nationmaster.com/time.php?stat=eco_rea_int_rat-economy-real-interest rate&country=my-malaysia.

[11] Fuller S. Life-Cycle Cost Analysis (LCCA) Hand Book. National Institute of Standards and Technology, Federal Energy Management Program 1995, revised in 2010, 2010 (accessed on 17 June 2011). Available from http://www.wbdg.org/design/lcca.php?print=1.

[12] Zhou W, Lou C, Li Z, Lu L, Yang H. Current Status of Research on Optimum Sizing of Stand alone Hybrid Solar–wind Power Generation Systems. App Ener 2010;87(2):380-389.

[13] Zondag HA, De Vries DW, Van Helden WGJ, Van Zolingen RJC, Van Steenhovena AA. The Yield of Different Combined PV-thermal Collector Designs. Sol Ener 2003;74:253-269.

[14] Iskander C, Scerri E. Performance and Cost Evaluation of a Standalone Photovoltaic System in Malta. WREC 1996;9(1-4):437-440.

[15] Groth A. Energy Efficiency Building Design Guidelines for Botswana. Department of Energy, Government of Botswana 2007. p. 1-224.

[16] Department of Land and Buildings and Real Estate. Guidelines for Life Cycle Cost Analysis. Stanford University, Project management, CA94305, 2005. p. 3-28.

[17] Larson RW. Economics of Solar Energy Technologies. American Solar Energy Society, 1992. p. 12-19.

[18] Diaf S, Notton G, Belhamel M, Haddadi M A. Design and Techno-economical Optimization for Hybrid PV/wind System under Various Meteorological Conditions. App Ener 2008;85: 968-987.

[19] Energy Technology Expert. How to calculate the Levelized Cost of Energy, 2009 (accesse on 25 February 2011). Available from http://energytechnologyexpert.com/cost-of-power generation/how-to calculate-the-levelized-cost-of-power-or-energy/.

[20] Celik AN. Present Status of Photovoltaic Energy in Turkey and Life Cycle Techno-economic Analysis of a Grid-connected Photovoltaic-house. Renew and Sust Ener Rev 2006;10:370-387.

[21] Lazou AA, Papatsoris AD. The Economic of Photovoltaic Stand-alone Residential Households: A Case Study for Various European and Mediterranean Locations. Department of Electronics, University of York, Heslington, York, UK, 2000. p. 411-427.

[22] Smullen J, Hand N. A Dictionary of Finance and Banking. Oxford University Press, 2005 (Accessed on 25 February 2011). Available from www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t20.

[23] Kishk M, Al-Hajj A, Pollock R, Aouad G, Bakis N, Sun M. Whole Life Costing in Construction, A State of the Art Review. RICS Foundation, 2003. p. 1-39.

[24] Flanagan R, Norman G, Meadows J, Robinson G. Life cycle costing theory and practice. BSP Professional Books, Oxford, 1995. p. 1-181.

[25] Schade J. Life Cycle Cost Calculation Models for Buildings. Department of Civil, Mining and Environmental Engineering, Luleå University of Technology, Luleå, Sweden 2007.

[26] International Organization for Standardization (ISO). Buildings and Constructed Assets-service Life Planning. (ISO/DIS 15686-5), 2004. p. 1-10.

[27] Vigneswaran A. Economic Evaluation of a Stand Alone PV System for a Residential Household in Malaysia. ME Thesis. Universiti Teknologi Malaysia, Malaysia, 2008.