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Comparison the economic analysis of the battery between lithium-ion and lead-acid in PV stand-alone application

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Abstract

This paper presents the economics analysis of 140 Wp photovoltaic (PV) stand-alone system by using a generic excel model. The main components of PV stand-alone system consist of 140 Wp PV module, 150 W inverter, and two different types of battery as lithium-ion and lead-acid battery. The economic analysis of this paper presents the cost of energy (COE), benefit cost ratio (BCR), and simple net present value (SNPV). From the results of this study show that the COE, BCR, and SNPV of PV stand-alone system, which using lithium-ion battery are 0.13, 34.93 baht/kWh and 145,927 baht, respectively. For the COE, BCR, and SNPV of PV stand-alone system, which using lead-acid battery are 0.19, 23.30 Baht/kWh and 89,143 Baht, respectively. Although the economic parameters show that the PV stand-alone which using lead-acid batteries is suitable than PV stand-alone that used lithium-ion battery. However, lithium-ion batteries have many advantages when compare with lead-acid battery technology as high energy density, low maintenance and the number of lifecycle is higher compared with lead-acid battery.

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Keywords: Economic analysis, Lithium-ion battery, PV stand-alone application

1. INTRODUCTION

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An energy shortage is continuously deteriorating. The main cause is the population and economic growth which results energy demand higher than energy consumption. In 2011, the total primary energy consumption has increased about 3.5% from the previous year [1]. Increasing energy consumption shown in Fig.1

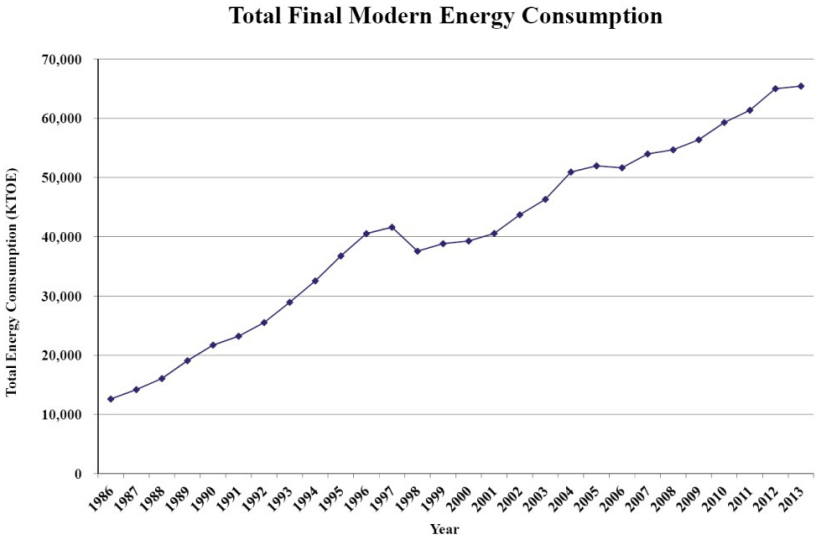

Fig.1. Total Energy Consumption from 1987 to 2011 [1]

According to energy shortage and environmental issues, it seems that for today and tomorrow, the priority choice of energy resource to produce electricity [2],[3]. Due to untercenties of renewable energy resource for electricity generation that does not match the energy consumption rate, therefore to achieve stability in electricity supply, the appropriate technology which able to store electricity is required.

The battery is an electric power supplies that is widely used. Battery is a device that stores energy for the electric power supply [4],[5]. Batteries are used in the electric energy storage for stand-alone photovoltaic systems during no sunlight [6]. The popular battery which is widely used is lead-acid battery, that is not expensive. However, it has some limitions : high maintenance, short lifetime, low capacity and low power density per unit weight. Trend of battery technology is focused on higher efficiency development with the proper size, shape, weight and low maintenance is also required. Battery is developed various features such as nickel metal hydride (Ni-MH), lithium ion (Li-ion) batteries etc.

The objective of the research is to compare the economic cost of lithium-ion batteries with lead-acid batteries in stand-alone photovoltaic system

2. STAND-ALONE PHOTOVOLTAIC SYSTEM

PV stand-alone system designed for the people in remote areas where is there is no electricity distribution networks. The working principle is divided into two periods (I) during the day, solar cell absorbs sunlight in order to produce electricity and supply to load as well as charge the excess electricity to batteries simultaneously (II) during the night, there is no sunlight. Solar cell cannot generate the electricity. Therefore, energy from the battery that charges during the day will be supplied to the load. The stand-alone photovoltaic system can supply electricity to the load both during the day and night. Main equipment of the system consists of solar panels, charge controllor, battery and inverter etc [6].

3. LITHIUM ION BATTERY

Lithium ion batteries have a lot of attention for its battery technology. They have many advantages for stand-alone photovoltaic system in comparison to lead acid battery [7]. Lithium ion batteries have high energy capacity, low maintenance and life cycle is higher than lead acid battery. Lithium ion batteries are also environment-friendly [8],[9]. Characteristics of the lead acid and lithium ion battery shown in Table 1 and type of lithium ion battery shown in Table 2.

Table 1. Characteristics of each battery types [10],[11].

Characteristics	Lead acid	Lithium ion
Energy Density (Wh/L)	54-95	250-360
Specific energy (Wh/kg)	30-40	110-175
Depth of discharge (DOD)	50%	80%
Temp range of Charge	-40°c – 27 °c	-20°c – 55 °c
Efficiency	75%	97%
Replacement timeframe (year)	1.5-2	5-7
Maintenance costs	SLA = 2% VRLA=10%	None
Battery Cost ($/kWh)	120 (3,840baht)	600 (19,200baht)

Table 2. Type of Lithium-ion battery [12].

Chemical name	Material	Abbreviation	Notes
Lithium Cobalt Oxide[1]	$LiCoO_2$ (60% Co)	LCO	High capacity; for cell phone laptop, camera
Lithium Manganese Oxide[1]	$LiMn_2O_4$	LMO	Most safe; lower capacity than Li-cobalt but high specific power and long life.
Lithium Iron Phosphate[1]	$LiFePO_4$	LFP	Power tools,
Lithium Nickel Manganese Cobalt Oxide[1]	$LiNiMnCoO_2$ (10–20% Co)	NMC	e-bikes, EV, medical, hobbyist.
Lithium Nickel Cobalt Aluminum Oxide[1]	$LiNiCoAlO_2$ (9% Co)	NCA	Gaining importance in electric powertrain and grid storage
Lithium Titanate[2]	$Li_4Ti_5O_{12}$	LTO	

[1] Cathode material [2] Anode material

4. THE SYSTEM DESIGN

This system studies economic costs of lithium-ion batteries compared to lead-acid batteries. It is a stand-alone photovoltaic system in rural area with peak power of the photovoltaic array (Ppeak) equal to 140 Wp. Amount of electrical energy that the stand-alone photovoltaic system produced is 156 kWh/ year. The system consists of solar array 140W/8Ah, Inverter with charge controller (Apollo S-120A), AC load and battery (Fig.2).

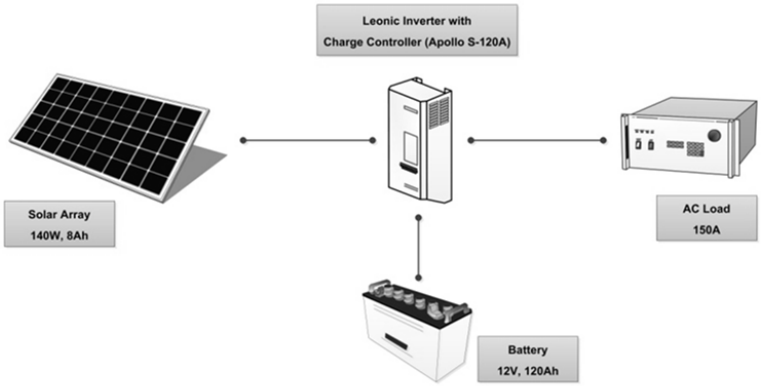

Fig.2. The system design

This study is divided into two case in the following.
Case 1 Lithium-ion battery (Winhub Technology Co., Ltd. LiFePO4: 120V 12Ah)
Case 2 use Lead acid battery (Globatt.N200: 200V 12Ah)

5. THE ECONOMIC ANALYSIS OF PHOTOVOLTAIC SYSTEM

This paper was considered the economics with the financial evaluation of photovoltaic system by using a generic Excel model and assessment of 140 W photovoltaic stand-alone system. Financial evaluation consists of two cases; evaluation in case of using lithium-ion batteries and evaluation in case of using lead-acid batteries for energy storage. Results of the financial evaluation were considered as follow conditions.

Conditions of the financial evaluation
a) Size of solar power generation system is 140 W.
b) The interest rate loan is 7.203% as shown in Table 3.

Table 3. The interest rate from banks [13].

Bank	MLR
Bank of Ayudhya (BAY)	7.375
Bangkok Bank (BBL)	7.000
Government Saving Bank (GSB)	7.250
Kasikorn Bank (K Bank)	7.000
Krung Thai Bank (KTB)	7.000
Siam Commercial Bank (SCB)	7.000
United Overseas Bank (UOB)	7.625

c) The performance of solar panels decreases by 1% per year.
e) Operation and maintenance system (O & M) by 1% of the initial investment per year.
f) Life time of the inverter is 14 years.
g) Life time of the lithium ion battery is 6 years, and lead acid battery is 2 years.
h) Power generation system will sell electricity all 365 days per year.
i) Price of 140 W photovoltaic systems is used in the financial evaluation.
j) The salvage value of the system is 5 % of the initial investment

Case 1 use Lithium-ion batteries for energy storage.
Photovoltaic system price in case 1 use lithium ion batteries for energy storage shown in Table 4.

Table 4. Photovoltaic system price.

No.	Item	Amount	Price/unit	Amount THB
1	PV panal	140	25	3,500
2	Inverter with charge controller	1	3400	3,400
3	Support structure.	140	12	1,680
4	Other devices	140	2	280
5	Lithium-ion battery (Winhub Technology Co., Ltd. LiFePO4 : 120V 12Ah)	1	30,720	30,720
6	Labor to install.	140	2.5	350
	Total Investment			39,930

Case 2 use Lead acid batteries for energy storage.
Photovoltaic system price in case 2 use lead acid batteries for energy storage shown in Table 5.

Table 5. Photovoltaic system price.

No.	Item	Amount	Price/unit	Amount THB
1	PV panal	140	25	3,500
2	Inverter with charge controller	1	3400	3,400
3	Support structure.	140	12	1,680
4	Other devices	140	2	280
5	Lead acid battery (Globatt.N200 : 200V 12Ah)	1	7,800	7,800
6	Labor to install.	140	2.5	350
	Total Investment			17,010

6. THE ECONOMIC ANALYSIS RESULT.

An evaluation on financial result of the photovoltaic stand-alone system
The results of the financial evaluation
Case 1 use Lithium-ion batteries for energy storage.
Case 2 use Lead acid batteries for energy storage.
The evaluation results are shown in Table 6

Table 6. An evaluation on financial result of the photovoltaic stand-alone system.

Parameters	Li-ion	Lead acid
Investment Cost (Baht)	39,930	17,010
LCB (Life Cycle Benefit)	12,234	12,032
LCC (Life Cycle Cost)	93,944	62,670
SNPV (Simple Net Present Value)	145,927	89,143
NPV (Net Present Value)	-81,711	-50,638
COE (Cost of Energy)	34.93	23.30
BCR (Benefit Cost Ratio)	0.13	0.19

From the study, it shows that installation investment of 140 W stand-alone PV using the Li-ion presents initial investment, which is 39,930 baht. Income over the life of the project (SNPV), cost of energy (COE), benefit cost ratio (BCR) are 145,927 baht, 34.93 baht and 0.13, respectively.

The initial investment lead acid battery is 17,010 baht. Income over the life of the project (SNPV) , cost of energy (COE), benefit cost ratio (BCR) are 89,143 baht, 23.30 baht and 0.19, respectively.

7. CONCLUSION

The results showed that the economic analysis of PV stand-alone using lead-acid battery are more suitable than PV stand-alone system using lithium-ion battery, because an initial investment cost of the lead-acid battery is cheaper than lithium-ion battery. However, lithium-ion batteries have many advantages in comparison to lead-acid battery technology because they have high energy density, low maintenance, environment friendly and lifecycle is higher than lead-acid battery.

Acknowledgements

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