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Economic Sustainability of Thermal Waste Management in Electric Vehicle Batteries

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ABSTRACT: The performance and life of a li-ion battery is affected by the working temperature of the battery, the heat generated when the battery is operating can cause problems with the battery, such as reducing its life and in the worst case an explosion will occur. This study aims to determine the economic feasibility of applying heat pipes to the disposal of thermal waste batteries for electric vehicles). Economic analysis is studied in terms of optimizing battery costs with a heat pipe cooling system against batteries without a cooling system. The process of calculating the economic value carried out includes calculating the BCR (Benefit Cost Ratio) value and NPV (Net Present Value) value. The BCR value obtained shows the number 1.28. The NPV value shows a figure of IDR 2,050,740 which exceeds the number 0. The use of heat pipes can be an alternative for managing battery thermal waste. The BCR value minimizes the level of risk from investing in a project or unit. The NPV value also shows that the project can be accepted economically and the next process can be carried out.

KEYWORDS: *Sustainable development*, *BCR*, *NPV*, *Battery*, *Thermal Waste*

I. INTRODUCTION

Sustainable development is a form of economic growth that will meet the needs and wants of the present without compromising the fulfillment of future needs. The concept of sustainable development consists of three aspects, namely environmental, social, and economic (Wang et al., 2019). Sustainability in the economic aspect is seen as economic viability that can survive in the long term despite changes in the economic context driven by variability in input and output prices and regulations. Economic viability can be measured through profitability, liquidity, stability and productivity. Profitability is calculated by comparing revenues and expenses either as a difference or as a ratio. Liquidity measures the availability of cash to meet short-term needs. Stability is usually measured by the share and development of equity models. Productivity is a measure of the ability of production factors to produce output (Latruffe et al., 2016)

This concept that does not only focus on the economic sector causes people to have to think about the environmental impacts it causes. Electric vehicles are one solution to the problem of environmental pollution because electric vehicles can reduce pollution and reduce carbon emissions. Electric vehicles require electrical energy to operate which energy is stored in batteries. The battery is an intermediary medium that serves to drain energy. Batteries are generally portable because they have a high energy density level and have a long service life cycle (Satriady et al., 2016). Several types of batteries commonly used include lead-acid batteries, lithium-ion batteries, and nickel metal hydride batteries (Hussain et al., 2019)

The performance of electric vehicles depends on the performance of the battery used. The performance and life of a li-ion battery is affected by the working temperature of the battery, the heat generated when the battery is operating can cause problems with the battery, such as reducing its life and in the worst case an explosion will occur (Yang et al., 2016). Studies show that working temperatures above 50 °C can harm battery life. Increasing the operating temperature of the battery above the optimum temperature range can accelerate the aging process of the battery, either in the components or the battery system and cause battery degradation. Several studies have stated that an excessive increase in the temperature of the battery can accelerate the degradation of the battery's capacity and lifespan (Zhang et al., 2014; Wang et al., 2016).

Along with the development of the world of transportation and the direction of SDG's policies, the development of battery-based electric vehicles continues to develop and increase production. In the future, electric power-based vehicles will be one type of vehicle with better potential in a sustainable manner in the future (Baral et al., 2021). The development of sustainable energy and environment has attracted a lot of public attention and the manufacture of high-efficiency heat transfer devices is urgently needed.

One of the heat transfer methods that can be used as an effort to increase battery life efficiency is the use of heat pipes (Putra et al., 2020). As a heat transfer device, the heat pipe has been considered to have a bright prospect due to its advantages such as simple structure, low cost and excellent heat transfer capability (Han et al., 2016). Apart from absorbing high heat flux, other characteristics of the heat pipe are that it does not require external power and there are no moving mechanical parts.

The application and development of battery coolers continues to develop along with the development of the application of science. Research from Feng et al. (2018) explained that research related to the treatment of thermal waste from batteries consists of the process of water cooling, liquid cooling, to the phase change of the shape of the material. The use of cooling in an effort to manage thermal waste is a simple method that allows to reduce or eliminate heat with the advantages of using low energy and being cost-effective (Chen & Li, 2020). In general, active cooling processes such as the use of air cooling or liquid cooling have an effect on increasing the volume, complexity of thermal waste treatment, and increasing costs in managing battery thermal waste treatment systems. This is different from the passive cooling process which tends to be used to keep the battery temperature in its optimal condition (Jiang & Qu, 2019). The basic purpose of applying the cooling process to the battery is to maintain the temperature of the battery when it is used (Tran et al., 2014). This is necessary so that the energy from the battery can be used optimally and the battery has a maximum functional life.

The feasibility of a system needs to be taken into account to determine the efficiency level between the costs incurred and the functions obtained. One of them is by calculating the value of benefit cost analysis. Calculation of the value of this is economic rationality, because the condition of economic rationality of a project needs to take into account the level of efficiency. The calculation consists of several calculation processes, including the calculation of NPV, to the calculation of BCR. The calculation of economic value is carried out by comparing the efficiency condition of the price which is then used to determine the marginal value of a project based on a comparison of the available economic value conditions (Vidia, 2015).

Applications related to energy renewal from batteries to the development process in transportation facilities need to pay attention to social aspects, especially the acceptance and perspective of the community as connoisseurs and users later (Omahne et al., 2021). In addition, social acceptance of renewable energy such as the application and development of electrical energy for transportation facilities can affect the implementation of policies that will be made (Paletto et al., 2019). Furthermore, from the aspect of social acceptance, it can be used to measure and determine the availability of energy resources available to local communities who need them and can consider the necessary economic, technical, and environmental aspects. This study aims to determine the economic feasibility of applying heat pipes to the disposal of thermal waste batteries for electric vehicles).

II. MATERIALS AND METHODS

The research approach taken in this study is quantitative. Economic analysis is studied in terms of optimizing battery costs with a heat pipe cooling system compares to batteries without a cooling system. The next process is calculating the economic value. The process of calculating the economic value carried out includes calculating the BCR value and NPV value.

The calculation of the BCR value is carried out to determine the magnitude of the value of the benefits of the research conducted based on the total value of the capital spent to carry out the research. This calculation is done by comparing the total costs incurred with a span of 20 years.

NPV calculation process to determine the value of the benefits of a project by calculating the value of the difference between the total value of discounted benefits obtained and the total value of discounted costs incurred on a project. The value of a project can be said to have a high benefit value if the calculated NPV value shows a high calculation value. The calculation of the NPV value can be done based on the following formula.

III. RESULTS AND DISCUSSION

The battery used in this study is a lithium-ion battery with type number 18650. The specifications of the battery in question are described in Table 1 as follows.

Table I. Specifications for 18650 Lithium-Ion Batteries

Parameter	Unit	Value
Type		US18650VTC4
Nominal voltage	V	3.7
Capacity	mAh	2100
Internal resistance	mΩ	12

Maximum voltage	V	4.2
Minimum voltage	V	3.2
Maximum discharge current	A	30
Minimum discharge current	A	6.5
Weight	gram	44

Thermal Waste Management Based on Heat Pipe in Batteries

The number of heat pipes used are 6 heat pipes with a flat shape that are connected or placed in the gap between the batteries. The number of batteries used was 8 lithium batteries with the specifications described in the previous chapter. It is showed that the life of the battery can increase from the risk of overheating that can occur if the thermal waste generated is not managed.

Economic Feasibility of Using Heat Pipe

The number of heat pipes used is 6 pieces with the required costs shown in Table as follows.

Table II. Heat Pipe Cost

Name of tools	**Total**	**Cost**
Heat pipe	6 unit	IDR 436.260 (IDR 145.420 per 2 pcs)

The level of feasibility of a unit or project can be analyzed by calculating the value of costs and value of benefits. The cost and benefit assessment process can be carried out using the BCR and NPV methods. The value of economic feasibility can be seen in the following table.

Table III. Economic Feasibility Value

Year	**Non Heat pipe**	**Heat pipe**
0	IDR 1.323.000	IDR 1.918.260
1	IDR -	IDR -
2	IDR -	IDR -
3	IDR 1.323.000	IDR -
4	IDR -	IDR -
5	IDR -	IDR 1.323.000
6	IDR 1.323.000	IDR -
7	IDR -	IDR -
8	IDR -	IDR -
9	IDR 1.323.000	IDR -
10	IDR -	IDR 1.323.000
11	IDR -	IDR -
12	IDR 1.323.000	IDR -
13	IDR -	IDR -
14	IDR -	IDR -
15	IDR 1.323.000	IDR 1.323.000
16	IDR -	IDR -
17	IDR -	IDR -
18	IDR 1.323.000	IDR -
19	IDR -	IDR -
20	IDR -	IDR 1.323.000
TOTAL	IDR 9.261.000	IDR 7.210.260
BCR	IDR1, 284419702	
NPV	IDR 2.050.740	

Economic Sustainability Thermal Waste Management in Electric Vehicle Batteries

The estimated lifetime of Lithium-Ion batteries under conditions of overheating can reduce battery life by up to 40% or a lifespan of only 3 years (Tektronix, 2022). The use of heat pipes can overcome excess heat so that it can optimize battery life up to 100% or 5 years. Based on Table 3, the BCR value obtained shows the number 1.28 with the division between the current value of benefits and the current cost value. This is in accordance with Sulianti & Tilik (2013) that to minimize the level of risk of investment in a project or unit, the value of the BCR must show more than one number. The NPV value shows the figure of IDR2,050,740 which exceeds the number 0. This means that the NPV number obtained is in accordance with Rumiyanto et al. (2015) that if the value of NPV> 1, then the proposed project can be accepted in economic value and the next process can be done.

IV. CONCLUSION

This study aims to determine the economic feasibility of applying heat pipes to the disposal of thermal waste batteries of electric vehicles. The BCR value obtained shows the number 1.28. This value minimizes the level of risk from investing in a project or unit. The NPV value shows a figure of IDR 2,050,740 which exceeds the number 0, so that the proposed project can be accepted economically and the next process can be carried out.

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REFERENCE

1) Baral, N. R., Asher, Z. D., Trinko, D., Sproul, E., Quiroz-Arita, C., Quinn, J. C., & Bradley, T. H. Biomass feedstock transport using fuel cell and battery electric trucks improves lifecycle metrics of biofuel sustainability and economy. *Journal of Cleaner Production*, 2021; 279, 123593. https://doi.org/10.1016/j.jclepro.2020.123593
2) Chen, Meng, & Li, J. (2020). Nanofluid-based pulsating heat pipe for thermal management of lithium-ion batteries for electric vehicles. Journal of Energy Storage, 32(July), 101715. https://doi.org/10.1016/j.est.2020.101715
3) Feng, L., Zhou, S., Li, Y., Wang, Y., Zhao, Q., Luo, C., Wang, G., & Yan, K. (2018). Experimental investigation of thermal and strain management for lithium-ion battery pack in heat pipe cooling. Journal of Energy Storage, 16, 84–92. https://doi.org/10.1016/j.est.2018.01.001
4) Han, G., Liang, C. Z., Chung, T. S., Weber, M., Staudt, C., & Maletzko, C. Combination of forward osmosis (FO) process with coagulation/flocculation (CF) for potential treatment of textile wastewater. *Water Research*, 2016; 91, 361–370. https://doi.org/10.1016/j.watres.2016.01.031
5) Hussain, F., Rahman, M. Z., Sivasengaran, A. N., & Hasanuzzaman, M. Energy storage technologies. In *Energy for Sustainable Development: Demand, Supply, Conversion and Management*. Elsevier Inc. 2019. https://doi.org/10.1016/B978-0-12-814645-3.00006-7
6) Jiang, Z. Y., & Qu, Z. G. (2019). Lithium–ion battery thermal management using heat pipe and phase change material during discharge–charge cycle: A comprehensive numerical study. Applied Energy, 242(February), 378–392. https://doi.org/10.1016/j.apenergy.2019.03.043
7) Latruffe, L., Diazabakana, A., Bockstaller, C., Desjeux, Y., Finn, J., Kelly, E., ... & Uthes, S. (2016). Measurement of sustainability in agriculture: a review of indicators. Studies in Agricultural Economics, 118(3), 123-130.
8) Omahne, V., Knez, M., & Obrecht, M. Social aspects of electric vehicles research—trends and relations to sustainable development goals. *World Electric Vehicle Journal*, 2021; 12(1), 1–13. https://doi.org/10.3390/wevj12010015
9) Paletto, A., Bernardi, S., Pieratti, E., Teston, F., & Romagnoli, M. Assessment of environmental impact of biomass power plants to increase the social acceptance of renewable energy technologies. *Heliyon*, 2019; *5*(7), e02070. https://doi.org/10.1016/j.heliyon.2019.e02070
10) Putra, N. W. S. (2014). *Teknologi Pipa Kalor*. UI-PRESS.
11) Rumiyanto, Irwan, H., & Purbasari, A. Analisa Studi Kelayakan Penambahan Mesin Cnc Baru Dengan Metode Npv (Net Present Value) Di PT. Usda Seroja Jaya Shipyard Batam. Profisiensi, 2015; 3(2), 151–159.
12) Satriady, A., Alamsyah, W., Saad, H. I., & Hidayat, S. PENGARUH LUAS ELEKTRODA TERHADAP KARAKTERISTIK BATERAI LiFePO 4. *Jurnal Material Dan Energi Indonesia*, 2016; *06*(02), 43–48.
13) Sulianti, I., & Tilik, L. F. Analisis Kelayakan Finansial Internal Rate of Return (IRR) dan Benefit Cost Ratio (BCR) pada Alternatif Besaran Teknis Bangunan Pasar Cinde Palembang. Pilar, 2013; 8(1).
14) Tektronix. Lithium-Ion Battery Maintenance Guidelines. 2022.
15) Tran, T. H., Harmand, S., Desmet, B., & Filangi, S. (2014). Experimental investigation on the feasibility of heat pipe cooling for HEV/EV lithium-ion battery. Applied Thermal Engineering, 63(2), 551–558.

https://doi.org/10.1016/j.applthermaleng.2013.11.048

16) Vidia, M. A. (2015). Proposed repeal of water saving regulations: cost benefit analysis. *Paper*
17) Wang, B., Xie, H. L., Ren, H. Y., Li, X., Chen, L., & Wu, B. C. Application of AHP, TOPSIS, and TFNs to plant selection for phytoremediation of petroleum-contaminated soils in shale gas and oil fields. *Journal of Cleaner Production*, 2019; 233, 13–22. https://doi.org/10.1016/j.jclepro.2019.05.301
18) Wang, Q., Jiang, B., Li, B., & Yan, Y. A critical review of thermal management models and solutions of lithium-ion batteries for the development of pure electric vehicles. *Renewable and Sustainable Energy Reviews*, 2016; 64, 106–128. https://doi.org/10.1016/j.rser.2016.05.033
19) Yang, Y., Huang, G., Xu, S., He, Y., & Liu, X. Thermal treatment process for the recovery of valuable metals from spent lithium-ion batteries. *Hydrometallurgy*, 2016; 165, 390–396. https://doi.org/10.1016/j.hydromet.2015.09.025
20) Zhang, S., Zhao, R., Liu, J., & Gu, J. Investigation on a hydrogel based passive thermal management system for lithium ion batteries. *Energy*, 2014; 68, 854–861. https://doi.org/10.1016/j.energy.2014.03.012