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# SELECTION OF ALTERNATIVE ENERGY SOURCES INDONESIAN WARSHIP PATROL CRAFT 36 CLASS USING LIFE CYCLE COST (LCC) AND TOPSIS (TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION)

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**ABSTRACT**

*Indonesia has abundant natural resources of oil and gas energy. Domestic fuel supply is not entirely fulfilled by domestic oil refineries, almost 20% -30% of domestic oil demand must be imported from abroad. This has an impact on the Navy. Steps to address this problem through switching to the use of alternative energy fuels for the Indonesian warship class Patrol Craft 36. The selection of appropriate alternatives requires analysis of information and identification of alternative fuel requirements to be selected. The approach in this study uses Life Cycle Cost method to see the life cycle cost of alternative and combined TOPSIS (Technique For Order Preference By Similarity To Ideal Solution) approach to other than cost factor, and Benefit Cost Ratio. The result of data processing of alternative energy sources selected is gas, CNG (Compressed Natural Gas) with the value of Benefit Cost Ratio 53,7051 Life Cycle Cost IDR 14,168,302,864.*

***Keywords:*** *Alternative Energy, Life Cycle Cost, TOPSIS.*

## 1. INTRODUCTION.

Geographically, Indonesia is an archipelago (archipelagic state) which is the largest total area, occupying nearly two-thirds of the Southeast Asian region (Adisasmita, 2006). The geographical position is located at the intersection of the world between the Indian Ocean and the Pacific Ocean as well as between Asia and Australia (UNCLOS , 1982). Based on this geographical location, Indonesia has abundant natural resources (Beatly, et al., 1994).

One of the abundant natural resources of oil and gas is the energy that becomes the mainstay of the Indonesian economy, both as a producer and supplier of foreign exchange in the country's energy needs. But in fact, the level of consumption of petroleum (oil) in the country has exceeded production capacity. In recent years, the supply of domestic fuel cannot be entirely met by domestic oil refineries, nearly 20% -30% of domestic oil needs had to be imported from abroad (LM FEUI Research Bureau, 2011).

The decrease in oil production was due to the decline in production from existing fields more quickly than expected. About 90 percent of Indonesia's total oil production is produced from the field whose age more than 30 years (MIGAS, 2016). So, it takes a considerable investment to curb the natural decrease. While oil reserves held generally categorized into groups unproven (believed to exist but have not been found) and proven (shown to be present and can be explored) with a certain degree of confidence.

Based on the above data source, even though Indonesia is one of the oil-producing countries, it still has not been able to meet domestic demand and this is a very big impact in Indonesia especially in the field of defense. Based on (The

Law of The Republic of Indonesia No.34, 2004) explains that ‘ the duty of the maritime security forces in the field of defense and law enforcement and to protect the maritime territories of national jurisdiction in accordance with the provisions of national law and ratified international law ‘ reinforced by national defense policy determined by the Ministry of Defense related to the Minimum Essential Force (MEF).

The Navy also feels the impact of fuel shortages. This is because most of the platforms (primary equipment, weapon system) that is possessed particularly Indonesian Warship Class Patrol Craft 36 that uses diesel fuel energy sources as the main motor drive. Looking for the main task, Indonesian Warship Class Patrol Craft 36 is a fast patrol fleet in the shallow marine waters that require a high level of mobility (Naval Headquarters, 2000).

Due to the needs for high fuel consumption for Indonesian Warship Class Patrol Craft 36 and the dependence on the availability of diesel fuel source, it requires the implementation of source selection for alternative waterwheel Indonesian Warship Class Patrol Craft 36. The selection of alternative energy source is also considered in terms of cost, both initial costs, operational and maintenance, and the risks of the alternative energy sources. To analyze the cost aspects, it has conducted research using Life Cycle Cost (LCC) method to measure the extent of the benefits and costs of each alternative. After knowing and evaluating the cost of each alternative, the weighting of selected alternatives is also done using TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method, resulting in a ranking of each alternative for selecting.

### 1.1 Related Works

(Burhanudin, 2002) explains the review of gas fuel development as an alternative fuel. Based on data sources predicted that the next 10 years will decrease crude oil production. Therefore, it is necessary to develop alternative energy sources, since 1987 the government has utilized gas fuel, which in terms of cheaper cost of fuel, lighter than air, machine age can last long, cheaper maintenance, and environmentally friendly. A study of (Dale, 2013) shows the development of renewable energy technologies. The energy sources studied are solar photovoltaic (PV), CSP (Concentrating Solar Power), and wind. This study is a comparative analysis of the three energy sources and calculate the energy cost used. Where seen from the Life Cycle Assessment aspect of each energy source. The results of this study found that the energy sourced from the wind has the cheapest energy costs followed by CSP, and then solar photovoltaic (PV). A study of raw material composite gear selection using MCDM method and Life Cycle Assessment. Selection of this composite raw material by considering from the aspect or criteria of mechanical, electrical, chemical cost, recycling process, and disposal. The result of this research is comparing gear making from pure PET raw material compared to PET composite / aluminum powder (A.S.Milani, et al., 2011). In a study (Firsani & Utomo, 2012) conducted using Life Cycle Cost (LCC) method in analyzing the construction of Diamond Building in Malaysia using the green building concept. Based on the concept required an analysis that sees how much the cost incurred. LCC analysis requires relevant costs, including initial costs, operational and maintenance costs, energy costs, replacement costs, and residual value. The analysis was performed by researchers using Present Worth Method, where the analysis period was determined for 10 years. (Mulyatno, 2010) conducted a technical study of the ship propulsion system using biodiesel fuel on Laboar vessels. This research is based on the study of fishermen's problems on the price of fuel which is increasingly expensive. So, developed alternative driving energy sources using biodiesel. Based on the results of the analysis and empirical calculations, the results show that efficiency when using diesel fuel when the ship is currently sailing is 23.2%, while the efficiency for B20 biodiesel fuel is 22.3%, B30 type is 23.2%, and type B50 is 22.1%. A comparative study of the use of emulsions of biodiesel mixed with DEE (Diethyl Ether) to produce an appropriate mixture of diesel engine performance. In addition, exhaust emissions produced by diesel engines can be reduced or reduced. The results of this study that the level of exhaust emissions specifically of NO can be reduced by up to 20%. Where the NO content is the most percentage of gas in air pollution (Kannan & R., 2011). (Wibawa & Alam, 2013) researchers conducted research on the use of alternative gas energy sources for driving traditional fishing vessels. Seeing the situation and conditions of rising unstable fuel supply prices. This study tried to use a dual fuel system that was applied to fishing boat engines. (Bakar, et al., 2009) conducts

research on the application of environmentally friendly machines using alternative CNG (Compressed Natural Gas) fuels. The research was carried out on diesel engines that were used as a means of transportation. The results of this study that exhaust emissions from CNG are very low and far above the machines that use gasoline or diesel fuel.

## 2. METHODOLOGY.

### 2.1. Life Cycle Cost

Life Cycle Cost procedures based on (G. Woodward, 1997) is as follows: (1) Considered elements of cost are all cash flows that occur during the life cycle of an asset. From the previous definition, LCC includes all expenses incurred, from acquisition to disposal at the end of his life.

(2) Defining cost structure involves grouping costs so as to define the potential trade-offs, to achieve optimum LCC. Properties set fee structure will depend on the depth and the extent of the LCC study. (3) Estimating the cost relationship is a mathematical expression that describes the approximate cost of an item or activity as a function of one or more independent variables. (4) The establishing LCC formulation method involves the selection of an appropriate methodology for evaluating the asset of LCC. According to the literature life cycle costs are all the expenditure related to the items since it is designed until it is no longer usable. Then the life-cycle costs can be combined into Eq. (1).

Life Cycle Cost = Initial Cost + Operating Costs + Maintenance Cost + Disposal Cost (1)

One of the indicators used as a decision making basis to analyze the cash flow is a method of NPW (Net Present Worth). NPW is the present value of all cash flows from now until the end. Some calculations in the NPW method (Net Present Worth), namely:

The present value factors of uniform sequence (look for the value of P if the value of A is known) can be obtained by using Eq. (2).

$= ( / \quad , \%, )$ (2)

(P; current equivalent value, A; cash flow in period-N, i; interest rate, N; period). The capital recovery factor of a uniform series (look for an A if the value of P is known) by using Eq. (3).

$=( / , \%, )$ (3)

(A; current cash flow of period to-N, P; Present value at period-N, i; interest rate, N; period). To obtain the value of NPW (Net Present Worth) can be obtained by using Eq. (4).

$= \Sigma \quad h \quad - \quad \Sigma \quad h$ (4)

## 2.2 TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

TOPSIS is based on the concept where the best selected alternative not only has the shortest distance from the positive ideal solution, but it also has the longest distance from the negative ideal solution (Hwang & Yoon, 1981). This concept is widely used in several Multi Criteria Decision Making models to solve problems in a practical decision. This is due to the concept is simple and easy to understand, efficient computing and has the ability to measure the relative performance of the alternatives in the decision of a simple mathematical form.

In general, the procedures of TOPSIS follow the steps as follows (Lai, et al., 1994): (1) Make a normalized decision matrix. (2) Make a weighted, normalized decision matrix. (3) Determine positive ideal solution matrix and negative ideal solution matrix. (4) Determine the distance between the value of each alternative with a positive ideal solution matrix and negative ideal solution matrix. (5) Determine the value of preference for each alternative.

TOPSIS requires a work rating of each alternative $A_i$ for each of the normalized $C_j$ criteria, as shown in the Eq. (5).

(5)

(i=1,2,...,m; j= 1,2,...,n)

The ideal $A^+$ positive solution and the ideal $A^-$ negative solution can be determined based on the normalized weighted ($y_{ij}$) rating as Eq. (6) and Eq. (7).

$^+ = ( ^+, \quad ^+, ..., )$ (6)

$^- = ( _1^-, _2^-, ..., )$ (7)

(i=1,2,...,m;j=1,2,...,n)

The distance between alternative A with the ideal solution can be seen in the Eq. (8).

$^+ = \sqrt{\Sigma ( ^+ - )^2}$ (8)

(i=1,2,...,m)

The distance between alternative A with the ideal negative solution can be seen in the Eq. (9).

$^- = \sqrt{\Sigma ( - ^-)^2}$ (9)

(i=1,2,...,m)

The proximity value of each alternative ($V_i$) can be seen in the Eq. (10).

(10)

(i=1,2,...,m)

## 3. RESULT AND DISCUSION.

The alternative object offered in this study is: (a) High Solid Diesel (b) Biodiesel (c) Compressed Natural Gas (CNG). The judges used in determining the sample to an expert in this study are those who have positions which can influence in the selection of alternative energy sources Indonesian Warship Patrol Craft Class 36, as Units of eligibility, Department of maintenance and repair, and Department of materials and supplies as consideration in the determination of the expert, and the recent experienced personnel type Patrol Craf Class 36. The calculation of Life Cycle Cost from each alternative is obtained based on total expenses incurred during 1 (one) year. The life cycle is calculated over a period of 25 (twenty five) years of age from Patrol Craft Class 36. The analysis used is a technical analysis of technical methods of Present Worth, then conducted an NPV analysis (Net Present Value). The criteria generated for the selection of alternative energy sources can be seen in Table 1.

**Table 1.** Criteria for Energy Sources Selections

| Criteria | Understanding / Parameter |
|---|---|
| Efficiency | The level of fuel consumption used. |
| The Main Machine | Type MAN machine with type D 282 LE 410. |
| Diesel Generator | Type Perkins type 4 TGM that produces a power of 50 KVA. |
| Fuel System | Fuel flow from the storage tank to machine and burning process. |
| Tank Capacity | The amount of fuel charge capacity to be stored at Patrol Craft 36 is 30,000 liters. |
| Budget Limitations | Ability to support in conducting operations. |
| Security | Impacts that can trigger an explosion or fire for Patrol Craft Class 36. |
| Transfer of Fuel | Fueling process at Indonesian Warship. Current condition of fuel transfer through among others bunker service, ground pipe Pertamina limited company , fuel trucks, and through Indonesian Warship (Assist Liquid Oil) Class while at sea. |
| Exhaust gas emissions | The remaining fuel combustion inside is discharged through the engine exhaust system. |
| Machine Room Temperature | Indicators during the combustion process that affect the temperature of the warship engine room. |

### 3.1 Life Cycle Cost Analysis Using Fuel HSD (Existing)

The use of HSD fuel is a current condition that does not require a current or initial investment cost. The costs consist of maintenance cost for replacement filters (fuel, air and oil), and the cost of fuel consumption. The estimated costs, which incurred using Eq. 1 for 1 (one) year in conducting the operations can be seen in Table 2.

**Table 2.** Estimated Cost of PC 36 Using Fuel HSD Over One Year

| Types of Costs | | | Total Cost |
|---|---|---|---|
| Investment Costs | | | |
| Operating Costs | IDR 6.500.000 | | IDR 26.000.000 |
| Maintenance Costs | | | |
| Fuel Filters | IDR 882.500 | 30 | IDR 26.475.000 |
| Air Filter | IDR 4.800.000 | 14 | IDR 67.200.000 |
| Oil Filter | IDR 482.500 | 14 | IDR 6. 755.000 |
| Fuel Costs | IDR 11.900 | 551.000 Ltr | IDR 6.556.900.000 |
| **Total** | | | **IDR 6.683.330.000** |

The calculation results of Life Cycle Cost using HSD fuel are of IDR 909.188.428.625, then to get the value of Net Present Worth (NPW) based on Eq. 4 can be seen in Table 3.

**Table 3.** Life Cycle Cost Use of HSD Fuel

| Year | Investment Cost | Operating Costs | Maintenance costs | Fuel costs | Total Present Cost | Total Annual Cost |
|---|---|---|---|---|---|---|
| 0 | | | | | | |
| 1 | | IDR 26,000,000 | IDR 100,430,000 | IDR 6,556,900,000 | IDR 6,683,330,000 | IDR 7,552,182,900 |
| 2 | | IDR 43,370,663 | IDR 167,537,528 | IDR 10,937,580,860 | IDR 11,148,479,051 | IDR 6,683,330,000 |
| 3 | | IDR 61,389,968 | IDR 237,138,555 | IDR 11,481,841,469 | IDR 11,780,361,992 | IDR 6,683,330,000 |
| 4 | | IDR 77,336,254 | IDR 298,728,155 | IDR 19,503,311,034 | IDR 19,879,375,444 | IDR 6,683,330,000 |
| 5 | | IDR 91,448,003 | IDR 353,235,536 | IDR 23,062,133,659 | IDR 23,506,817,207 | IDR 6,683,330,000 |
| 6 | | IDR 103,938,295 | IDR 401,473,925 | IDR 26,211,534,211 | IDR 26,716,944,431 | IDR 6,683,330,000 |
| 7 | | IDR 114,907,871 | IDR 444,182,768 | IDR 28,998,614,346 | IDR 29,557,704,983 | IDR 6,683,330,000 |
| 8 | | IDR 124,768,023 | IDR 481,948,501 | IDR 31,465,058,944 | IDR 32,071,765,472 | IDR 6,683,330,000 |
| 9 | | IDR 133,423,093 | IDR 515,372,124 | IDR 33,647,749,358 | IDR 34,296,544,865 | IDR 6,683,330,000 |
| 10 | | IDR 141,082,358 | IDR 544,957,602 | IDR 35,578,335,847 | IDR 36,265,375,818 | IDR 6,683,330,000 |
| 11 | | IDR 147,860,469 | IDR 571,139,449 | IDR 37,288,764,290 | IDR 38,007,764,257 | IDR 6,683,330,000 |
| 12 | | IDR 153,858,822 | IDR 594,308,290 | IDR 38,801,439,725 | IDR 39,549,587,838 | IDR 6,683,330,000 |
| 13 | | IDR 159,167,108 | IDR 614,813,551 | IDR 40,140,105,952 | IDR 40,914,086,582 | IDR 6,683,330,000 |
| 14 | | IDR 163,864,686 | IDR 632,958,877 | IDR 41,324,764,023 | IDR 42,121,587,586 | IDR 6,683,330,000 |
| 15 | | IDR 168,021,849 | IDR 649,016,705 | IDR 42,373,171,706 | IDR 43,190,210,260 | IDR 6,683,330,000 |
| 16 | | IDR 171,700,752 | IDR 663,227,179 | IDR 43,300,948,413 | IDR 44,135,876,337 | IDR 6,683,330,000 |
| 17 | | IDR 174,956,457 | IDR 675,802,888 | IDR 44,121,989,746 | IDR 44,972,748,971 | IDR 6,683,330,000 |
| 18 | | IDR 177,837,538 | IDR 686,931,488 | IDR 44,848,574,996 | IDR 45,711,344,022 | IDR 6,683,330,000 |
| 19 | | IDR 180,387,283 | IDR 696,780,255 | IDR 45,491,578,785 | IDR 46,368,728,259 | IDR 6,683,330,000 |
| 20 | | IDR 182,643,541 | IDR 705,495,801 | IDR 46,060,595,632 | IDR 46,948,732,964 | IDR 6,683,330,000 |
| 21 | | IDR 184,640,302 | IDR 713,208,675 | IDR 46,564,153,648 | IDR 47,461,982,623 | IDR 6,683,330,000 |
| 22 | | IDR 186,407,347 | IDR 720,034,224 | IDR 47,009,781,989 | IDR 47,916,223,958 | IDR 6,683,330,000 |
| 23 | | IDR 187,971,183 | IDR 726,074,555 | IDR 47,404,148,335 | IDR 48,318,188,996 | IDR 6,683,330,000 |
| 24 | | IDR 189,354,959 | IDR 731,419,942 | IDR 47,753,155,711 | IDR 48,673,930,612 | IDR 6,683,330,000 |
| 25 | | IDR 190,579,689 | IDR 736,150,591 | IDR 48,061,978,595 | IDR 48,988,708,596 | IDR 6,683,330,000 |
| | | | | TOTAL | IDR 909,188,428,625 | IDR 167,952,082,900 |

### 3.2 Life Cycle Cost Analysis Using Biodiesel Fuel

Based on the analysis of the characteristics and fuel systems for the use of biodiesel fuel for PC 36, it does not need a change of engine and fuel system. The operating and maintenance costs of PC 36 using HSD fuel are the same as using Biodiesel fuel due to the same fuel system. But differ in the calculation of fuel consumption costs. Thus, estimates of the costs incurred when using biodiesel fuel for 1 (one) year can be seen in the Table 4.

**Table 4.** Estimated Cost of PC 36 Using Fuel Biodiesel Over One Year

| Types of Costs | | | Total Cost |
|---|---|---|---|
| Investment Costs | | | |
| Operating Costs | IDR 6.500.000 | | IDR 26.000.000 |
| Maintenance Costs | | | |
| Fuel Filters | IDR 882.500 | 30 | IDR 26.475.000 |
| Air Filter | IDR 4.800.000 | 14 | IDR 67.200.000 |
| Oil Filter | IDR 482.500 | 14 | IDR 6. 755.000 |
| Fuel Costs | IDR 9.250 | 551.000 Ltr | IDR 5.096.750.000 |
| **Total** | | | **IDR 5.223.180.000** |

Obtained cost estimates using biodiesel fuel for the Life Cycle Cost above are IDR 710.552 .197.277, then to get the value of Net Present Worth can be seen in Table 5.

**Table 5.** Life Cycle Cost Using Biodiesel Fuel

| Year | Investment Cost | Operating Costs | Maintenance costs | Fuel costs | Total Present Cost | Total Annual Equivalent Cost |
|---|---|---|---|---|---|---|
| 0 | | | | | | |
| 1 | | IDR 26.000.000 | IDR 100.430.000 | IDR 5.096.750.000 | IDR 5.223.180.000 | IDR 5.902.195.400 |
| 2 | | IDR 45.370.665 | IDR 167.527.538 | IDR 8.501.901.089 | IDR 8.712.798.280 | IDR 5.223.180.000 |
| 3 | | IDR 61.389.968 | IDR 237.130.595 | IDR 12.034.204.563 | IDR 12.332.725.026 | IDR 5.223.180.000 |
| 4 | | IDR 77.334.294 | IDR 298.726.195 | IDR 15.180.136.730 | IDR 15.556.198.158 | IDR 5.223.180.000 |
| 5 | | IDR 91.448.013 | IDR 353.235.556 | IDR 17.926.448.412 | IDR 18.371.131.981 | IDR 5.223.180.000 |
| 6 | | IDR 105.936.295 | IDR 401.471.925 | IDR 20.374.511.087 | IDR 20.879.822.107 | IDR 5.223.180.000 |
| 7 | | IDR 114.987.071 | IDR 444.162.766 | IDR 22.540.699.725 | IDR 23.100.095.560 | IDR 5.223.180.000 |
| 8 | | IDR 124.768.023 | IDR 481.940.581 | IDR 24.458.132.490 | IDR 25.064.841.027 | IDR 5.223.180.000 |
| 9 | | IDR 133.425.033 | IDR 515.372.134 | IDR 26.154.760.273 | IDR 26.803.558.441 | IDR 5.223.180.000 |
| 10 | | IDR 141.082.330 | IDR 544.957.622 | IDR 27.656.206.636 | IDR 28.342.246.599 | IDR 5.223.180.000 |
| 11 | | IDR 147.860.469 | IDR 571.139.498 | IDR 28.984.917.200 | IDR 29.703.917.167 | IDR 5.223.180.000 |
| 12 | | IDR 153.859.022 | IDR 594.309.280 | IDR 30.160.767.454 | IDR 30.908.935.546 | IDR 5.223.180.000 |
| 13 | | IDR 159.167.106 | IDR 614.813.551 | IDR 31.201.342.002 | IDR 31.975.322.482 | IDR 5.223.180.000 |
| 14 | | IDR 163.864.690 | IDR 632.958.877 | IDR 32.122.206.072 | IDR 32.918.029.659 | IDR 5.223.180.000 |
| 15 | | IDR 168.021.849 | IDR 649.016.785 | IDR 32.937.129.267 | IDR 33.754.167.902 | IDR 5.223.180.000 |
| 16 | | IDR 171.700.752 | IDR 663.227.173 | IDR 33.658.300.257 | IDR 34.493.228.181 | IDR 5.223.180.000 |
| 17 | | IDR 174.956.417 | IDR 675.802.800 | IDR 34.296.504.654 | IDR 35.147.263.859 | IDR 5.223.180.000 |
| 18 | | IDR 177.837.558 | IDR 686.931.680 | IDR 34.861.287.287 | IDR 35.726.056.513 | IDR 5.223.180.000 |
| 19 | | IDR 180.387.201 | IDR 696.780.255 | IDR 35.361.094.944 | IDR 36.238.262.401 | IDR 5.223.180.000 |
| 20 | | IDR 182.643.541 | IDR 705.495.801 | IDR 35.803.402.605 | IDR 36.691.541.948 | IDR 5.223.180.000 |
| 21 | | IDR 184.640.302 | IDR 713.208.673 | IDR 36.194.825.315 | IDR 37.092.674.290 | IDR 5.223.180.000 |
| 22 | | IDR 186.407.347 | IDR 720.034.224 | IDR 36.541.217.093 | IDR 37.447.658.664 | IDR 5.223.180.000 |
| 23 | | IDR 187.971.105 | IDR 726.074.558 | IDR 36.847.758.489 | IDR 37.761.804.152 | IDR 5.223.180.000 |
| 24 | | IDR 189.354.959 | IDR 731.419.842 | IDR 37.119.034.060 | IDR 38.039.808.862 | IDR 5.223.180.000 |
| 25 | | IDR 190.579.609 | IDR 736.150.391 | IDR 37.359.100.939 | IDR 38.285.830.940 | IDR 5.223.180.000 |
| | | | | TOTAL | IDR 710.552.197.277 | IDR 131.258.513.400 |

### 3.3 Life Cycle Cost Analysis Using Compressed Natural Gas Fuel

The use of CNG fuel of PC 36 is based on the analysis of the characteristics and fuel systems, so a change of system flow of fuel and fuel tank design is needed. The CNG fuel system does not require the use of the fuel filter resulting the replacement costs nothing. The overall cost of installation of conversion kits in the fuel system of PC 36 is IDR 80.000.000. The Cost of 1 (one) CNG tube is 300 USD and the lifetime for 6 (six) years with the exchange rate IDR 12.156. These costs represent the investment costs to be incurred, so that the estimated costs of PC 36 using CNG fuel for 1 (one) year can be seen in the following Table 6.

**Table 6.** Estimated Cost of PC 36 Using Fuel CNG Over One (1) Year

| Types of Costs | | | Total Cost |
|---|---|---|---|
| Investment Costs | | | |
| Kit Converter | IDR 80.000.000 | | |
| CNG Tube | IDR 18.234.000 | | IDR 98.234.000 |
| Operating Costs | IDR 6.500.000 | | IDR 26.000.000 |
| Maintenance Costs | | | |
| Fuel Filters | | | |
| Air Filter | IDR 4.800.000 | 14 | IDR 67.200.000 |
| Oil Filter | IDR 482.500 | 14 | IDR 6. 755.000 |
| Fuel Costs | IDR 3.100 | 551.000 Ltr (551 $m^3$) | IDR 1.708.100.000 |
| **Total** | | | **IDR 1.906.289.000** |

The calculation results of Life Cycle Cost above obtained results of IDR 14.163.302.864, so to get the value of Net Present Worth (NPW) can be seen in Table 7.

**Table 7.** Life Cycle Cost Using CNG Fuel

| Year | Investment Cost | Operating Costs | Maintenance costs | Fuel costs | Total Present Cost | Total Annual Equivalent Cost |
|---|---|---|---|---|---|---|
| 0 | IDR [illegible] | | | | IDR [illegible] | |
| 1 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 2 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 3 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 4 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 5 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 6 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 7 | IDR 80.000.000 | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 8 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 9 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 10 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 11 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 12 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 13 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 14 | IDR 80.000.000 | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 15 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 16 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 17 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 18 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 19 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 20 | IDR 80.000.000 | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 21 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 22 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 23 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 24 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| 25 | | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] | IDR [illegible] |
| | | | | TOTAL | IDR [illegible] | IDR [illegible] |

### 3.4 Saving Total Annual Equivalent Cost Each Alternative

Saving Calculation Total Annual Equivalent Fuel cost is derived from the delta (Δ) saving Total Annual Equivalent Cost from the comparison of each fuel usage seen in the figure 1.

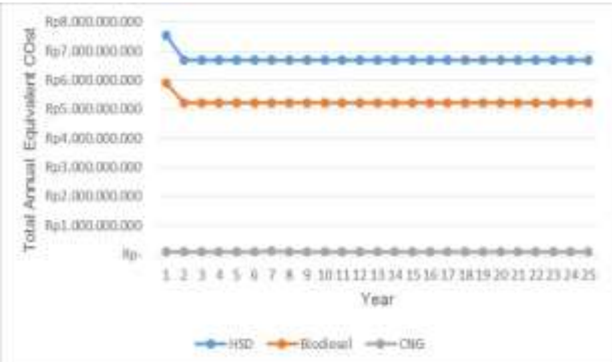


**Fig. 1** Comparison Charts Total Annual Equivalent Costs Each Alternative

From the calculation of (delta) Total Annual Equivalent Cost savings above, it is explained that annual equivalent cost of the largest fuel if the fuel utilization ratio HSD was used CNG gas fuel in the amount of IDR 165.355.118.630. It can be seen in Table 8.

**Table 8.** Delta (Δ) Total Annual Equivalent Cost Saving Fuel

| Fuel | Total Annual Cost | (Δ) Saving |
|---|---|---|
| HSD – Biodiesel | IDR 167.952.082.900 – IDR 131.258.513.400 | IDR 36.693.569.500 |
| HSD – CNG | IDR 167.952.082.900 – IDR 2.596.964.270 | IDR 165.355.118.630 |
| Biodiesel – CNG | IDR 131.258.513.400 – IDR 2.596.964.270 | IDR 128.661.549.130 |

### 3.5 Sensitivity Analysis

This sensitivity analysis is a change of Life Cycle Cost to the interest rate (i) with the range of ± 30%. Then the Life Cycle Cost sensitivity to interest rate changes (i) can be seen in the Table 9.

**Table 9.** LCC Sensitivity to Interest Rate Changes

| Interest rate (i) | Percentage of Cumulative Changes (i) | Fuel | | |
|---|---|---|---|---|
| | | HSD | Biodiesel | CNG |
| 16,90% | 30% | IDR 760.341.592.242 | IDR 594.224.884.566 | IDR 11.904.127.548 |
| 15,60% | 20% | IDR 804.645.911.085 | IDR 628.849.754.518 | IDR 12.578.060.213 |
| 14,30% | 10% | IDR 853.986.815.531 | IDR 667.410.834.890 | IDR 13.328.606.618 |
| 13% | 0% | IDR 909.188.428.625 | IDR 710.552.197.277 | IDR 14.168.302.864 |
| 11,70% | -10% | IDR 971.246.548.361 | IDR 759.052.081.293 | IDR 15.112.296.476 |
| 10,40% | -20% | IDR 1.041.371.280.878 | IDR 813.856.213.423 | IDR 16.178.994.918 |
| 9,10% | -30% | IDR 1.121.041.808.105 | IDR 876.120.609.226 | IDR 17.390.898.681 |

The result of the LCC's sensitivity analysis of interest rate changes is found that with the change of interest rate increases up to 30% obtained the smaller LCC results for each fuel and vice versa if the change of interest rate is reduced to 30%, the LCC result of each fuel will get bigger.

### 3.6 Processing TOPSIS Analysis

Collecting data to calculate by using TOPSIS method is derived from expert interviews and a literature study for the selection of an alternative energy source for the Indonesian Warship PC 36 class that has been implemented. The results of the data obtained by the raised criteria in the selection of alternative energy sources for the PC 36 class. The initial form matrix can be seen in the Table 10.

**Table 10.** Matrix Initial Formation

| NO. | CRITERIA | HSD | BIODIESEL | CNG | SCORE | |
|---|---|---|---|---|---|---|
| 1. | Efficiency | 2,2000 | 3,9000 | 4,4000 | X1 | 6,2777 |
| 2. | The Main Machine | 3,5000 | 3,2000 | 3,2000 | X2 | 5,7210 |
| 3. | Diesel Generator | 3,6000 | 3,2000 | 3,3000 | X3 | 5,8387 |
| 4. | Fuel System | 4,5000 | 4,4000 | 1,9000 | X4 | 6,5742 |
| 5. | Tank Capacity | 4,5000 | 4,5000 | 1,8000 | X5 | 6,6136 |
| 6. | Budget Limitations | 2,9000 | 3,8000 | 4,9000 | X6 | 6,8454 |
| 7. | Security | 4,4000 | 4,4000 | 1,8000 | X7 | 6,4777 |
| 8. | Transfer of Fuel | 3,8333 | 3,3333 | 4,5000 | X8 | 6,7864 |
| 9. | Exhaust gas emissions | 2,8333 | 4,0000 | 4,5000 | X9 | 6,6542 |
| 10. | Machine Room Temperature | 2,8333 | 4,1667 | 4,6667 | X10 | 6,8678 |

This was followed by finding a normalized decision matrix of the initial matrix by using the Equation (5). The normalized decision matrix is at the following Table 11.

**Table 11.** Normalized Decision Matriks

| HSD | BIODIESEL | CNG |
|---|---|---|
| 0,3504 | 0,6212 | 0,7009 |
| 0,6118 | 0,5593 | 0,5593 |
| 0,6166 | 0,5481 | 0,5652 |
| 0,6845 | 0,6693 | 0,2890 |
| 0,6804 | 0,6804 | 0,2722 |
| 0,4236 | 0,5551 | 0,7158 |
| 0,6793 | 0,6793 | 0,2779 |
| 0,5649 | 0,4912 | 0,6631 |
| 0,4258 | 0,6011 | 0,6763 |
| 0,4126 | 0,6067 | 0,6795 |

The next is determining the positive ideal solution and negative ideal solution. The positive ideal solution is according to the Eq. (6) and the negative ideal solution is according to the Eq. (7). As a result, the positive and negative ideal solution is in the following Table 12.

**Table 12.** Positive and Negative Ideal Solution

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive Ideal Solution (A+) | 0,7009 | 0,6118 | 0,6166 | 0,6845 | 0,6804 | 0,7158 | 0,6793 | 0,6631 | 0,6763 | 0,6795 |
| Negative Ideal Solution (A-) | 0,3504 | 0,5593 | 0,5481 | 0,289 | 0,2722 | 0,4236 | 0,2779 | 0,4912 | 0,4258 | 0,4126 |

Calculate the alternate distances. Alternative distance with positive ideal solution is according to the Eq. (8) and the distance alternative to the negative ideal solution is according to the formula (9). Therefore, we get an alternative distance with a positive ideal solution and alternative distance with negative ideal solution at the following table 13.

**Table 13.** Positive and Negative Alternative Distance

| Alternative Distance With Positive Ideal Solution | | |
|---|---|---|
| (D1+) | 0,5931 | HSD |
| (D2+) | 0,2834 | BIODIESEL |
| (D3+) | 0,6997 | CNG |
| **Alternative Distance With Negative Ideal Solution** | | |
| (D1-) | 0,705 | HSD |
| (D2-) | 0,7946 | BIODIESEL |
| (D3-) | 0,6099 | CNG |

Calculate the closeness of each alternative against the ideal solution, using the Eq. (10). So the proximity of each alternative is obtained as a Table. 14. **Table 14.** Proximity of Each Alternative

| | HSD | Biodiesel | CNG |
|---|---|---|---|
| Vi | 0,5431 | 0,7371 | 0,4657 |

Eventually gained alternative ranking based on the relative closeness as follows: Biodiesel: 0.7371, HSD: 0.5431, CNG: 0.4657.

## 4. CONCLUSION.

From the results of data collection and processing, and analysis of data processing, Based on research by the method of Life Cycle Cost for the selection of an alternative energy source for the KRI Class PC 36, it can be concluded as follows: (a) Category costs contained in the selection of alternative energy sources for KRI Class PC 36, which are the initial cost (investment), operating costs, maintenance costs, and the cost of fuel (fuel cost). (b) Total Life Cycle Cost of each alternative, namely, for HSD fuel IDR 909,188,428,625, while for biodiesel fuel IDR 710,552,197,277, and for the use of CNG fuel is IDR 14,168,302,864. (c) Priority selection of alternative energy sources using the Life Cycle Cost is the use of CNG gas type fuel, biodiesel fuel, and the last HSD fuel (existing).

Selection of alternative fuels for KRI Class PC 36 with TOPSIS approach derived criteria for the selection of alternative fuels. These criteria are efficient, MPK machine, DG (Diesel Generator), fuel system, tank capacity, budget constraints, safety, fuel transfer, emissions, and the temperature of the engine room, and the next election results obtained from respondents in a sequence are biodiesel fuel, HSD fuel (existing), and CNG gas fuel.

Selection using TOPSIS approach that given to the respondents has no influence on the cost factor. Hence, to see the effect of the cost factor or Life Cycle Cost on the results of the calculation processing TOPSIS Benefit Cost Ratio, the results of calculations use the Benefit Cost Ratio which gets the greatest value is the chosen alternative. Sequentially, alternative priorities chosen by the Benefit Cost Ratio that is the fuel type with a value of 53.7051 CNG gas, biodiesel fuel with a value of 1.6949, and last priority is HSD fuel with a value of 0.9760.

## 5. BIBLIOGRAPHY.


A.S.Milani, et al., 2011. Multiple Cirteria Decision Making With Life Cycle Assesment For Material Selection Of Composites. *eXPRESS Polymer Letters,* 5(12), pp. 1062-1074.

Adisasmita, R., 2006. *Marine and Territorial Developement.* Yogyakarta: Graha Ilmu.

Bakar, R., Semin & Ismail, A., 2009. Green Engines Development Using Compressed Natural Gas as an Alternative Fuel. *AMerican Journal of Environmental Sciences ,* pp. 371-381.

Beatly, T., Brower, D. J. & Schwab, A. K., 1994. *An Introducting to Coastal Zone Management.* Washington DC: Island Press.

Burhanudin, T., 2002. *REVIEW OF FUEL GAS EXPOSURE AS A FUEL ALTERNATIVE,* Medan, Indonesia: USU Digital Library.

Dale, M., 2013. Comparative Analysis of Energy Costs of Photovoltaic, Solar Thermal, and Wind Electricity Generation Technologies. *Applied Sciences ,* Volume 3, pp. 325-337.

Firsani, T. & Utomo, C., 2012. Life Cycle Cost Analysis on Green Building Diamond Building Malaysia. *ITS Journals,* 1(1), pp. D34-D39.

G. Woodward, D., 1997. Life cycle costing—Theory, information acquisition and application. *International Journal of Project Management,* 15(6), pp. 335-344.

Hwang, C. & Yoon, K., 1981. *Multiple Attribute Decision Making: Methods and Applications.* New York: Springer-Verlag.

Kannan, T. & R., M., 2011. Comparative Study of Performance and Emission Characteristics of a Diesel Engine Fueled by Emulsified Biodiesel/Diethyl Ether Blended Biodiesel. *Journal of Applied Sciences ,* pp. 2961-2967.

Lai, Y.-J., Liu, T.-Y. & Hwang, C.-L., 1994. TOPSIS for MODM. *European Journal of Operational Research,* 76(3), pp. 486-500.

LM FEUI Research Bureau, 2011. *Analysis of Oil and Gas Industry in Indonesia: Input Share BUMN*

*Management,* Jakarta: Institute of Management Faculty of Economics, University of Indonesia.

MIGAS, S., 2016. *Annual Report on Upstream Oil and Gas Business Activities,* Jakarta: Ministry of Energy and Natural Resources.

Mulyatno, I. P., 2010. *Technical Study of Ship Driving System Performance Using Biodiesel Fuel on Vessels Laboar.* Semarang: Fakultas Teknik Universitas Diponegoro.

Naval Headquarters, 2000. *Indonesian Warship Combat Manual Patrol Craft 36.* Jakarta: Indonesian Navy.

The Law of The Republic of Indonesia No.34, 2004. *Indonesian National Armed Forces.* Jakarta: President of the Indonesian Republic.

UNCLOS , 1982. *Oceans and Law of The Sea.* Montego Bay: United Nations.

Wibawa, A. & Alam, R. S., 2013. Alternative Energy Utilization of Compressed Natural Gas as Fuel for Traditional Fishing Vessels. *Jurnal Jurusan Teknik Perkapalan Universitas Diponegoro.*