THE ASSESSMENT OF ENERGY ALTERNATIVE RESOURCES DEVELOPMENT ON MARITIME FIELDS USING PEST AND FUZZY MCDM METHODS

Sutrisno, Avando Bastari, Okol Sri Suharyo

Abstract. Indonesia has a national jurisdiction area of ± 7.8 million km² with 2/3 of its territory being the sea of ± 5.9 million km². With this large sea area, it is a great potential for Indonesia to be able to develop alternative energy resources in the maritime sector amid the problem of fossil energy resources whose capacity is decreasing. The energy crisis requires the government to encourage the development and utilization of new and renewable energy Alternative energy in the maritime sector that can be developed include energy that utilizes ocean waves, ocean currents, tides, and ocean temperature differences. This study aims to determine the alternative energy of the maritime sector by reviewing from technical and financial aspects, political, economic, social and technological aspects. The method used is technical analysis, financial analysis, PEST analysis, and Fuzzy MCDM. The first step in this process is the mapping of the technical, financial, political, economic, social and technological aspects of each energy alternative with technical, financial and PEST analysis. Furthermore, with the Fuzzy MCDM method an alternative energy development selection model was made by assessing the performance of each. The results of the analysis in the form of the concept of ranking alternative energy sources as a maritime potential that can be used as consideration in determining government policies in the energy sector.

Keywords: Alternative Energy Resources, PEST, Fuzzy MCDM.

1. INTRODUCTION

Indonesia has a national jurisdiction area of ± 7.8 million km² with 2/3 of its territory is the sea of ± 5.9 million km², which covers the Indonesian Exclusive Economic Zone (EEZ) of ± 2.7 million km² and the Regional Sea, Aquatic Islands and Inland waters covering ± 3.2 million km². Besides, it has a coastline length of ± 81,000 km and has 17,499 islands consisting of 5,698 islands named and 11,801 islands that are not / have not been named (Department of Hydrography and Oceanography, 2004). The use of energy in Indonesia is still dominated by the use of non-renewable energy derived from fossils, especially petroleum and coal. Current conditions, the availability of fossil energy are running low [7]. To anticipate the limitations of fossil energy, new renewable energy is an alternative that can be developed to meet Indonesia's energy needs. This condition encourages the government to use new and renewable energy to meet energy needs. With the condition of Indonesia's marine waters 2/3 of the total area, Indonesia has the potential to overcome the problem of the fossil energy crisis by developing alternative energy resources in the maritime sector such as current, wave, tidal or ocean thermal energy. The energy resource sector is critical because it is related to the livelihoods of the people of Indonesia and affects the country's macroeconomy. The development of alternative energy resources requires enormous resources. Therefore we need a calculation and strategic consideration to decide on a choice in the development of the maritime sector energy resources. Important factors in this development are influenced by considerations from financial, political, economic, social and technological aspects [8].

This research has some literature which is used as a support in conducting research such as research with the title Potential Of Sea Flow Energy As A Renewable Energy Source (Renewable Energy) On The Capalulu Holiday, North Maluku [6], Renewable energy production in the Łódzkie Voivodeship. The PEST analysis of the RES in the voivodeship and Poland [4], Establishing the Location of Naval Base Using Fuzzy MCDM and Covering Technique Methods: A Case Study [14]. The application of CBA and SUG models for improving the quality of Indonesian navy human resources [1], Applied Fuzzy and Nasa TLX method to measure the mental workload of Navy personnel [2], The relationship model of maritime culture and state policy towards national resilience for improving navy personnel [3], the Development strategy of national food sovereignty to encounter radicalism threat [5], The system dynamic model for policy evaluation of navy personnel on state-duty aspects [9], Analysis and scenario of navy performance allowance policy using the dynamic system model [10], and The naval harbors priority development using the zero-one matrix decision variable (ZOMDV) and Fuzzy MCDM methods [13] In this research, the writer uses Fuzzy MCDM analysis to determine the potential of alternative energy resources that can be considered by the government to be developed. The first step in this process is the mapping of the political, economic, social and technological sectors of each alternative energy with a PEST analysis. Furthermore, with the application of the Fuzzy MCDM method, alternative energy development selection models are made by assessing the performance of each. The results of this study can be used as a reference for developing the potential of alternative energy resources in the maritime sector. This paper is divided into several parts, namely the second part of the Material and Methodology, the third part of the results of research and discussion and the fourth section of conclusions.

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2. MATERIAL AND METHODS

2.1 Potential Alternative Sources of Energy in the Maritime Sector

A simple division of energy can be divided into two, namely renewable energy and non-renewable energy. Renewable energy is the energy that utilizes renewable resources such as wind power, solar power, tides, and biofuels. Non-renewable energy is the energy that has a time-limited supply such as energy derived from fossils such as petroleum. Until now, petroleum is still the main source of energy in meeting domestic needs. However, the availability of energy derived from fossils is an important issue because of the depletion of petroleum reserves which can directly threaten the supply of fuel and electricity for the community. The maritime sector is very interested in this energy issue because the sea holds great potential as an alternative energy source so it is very potential to be developed. Marine energy is a term used to describe all forms of renewable energy that can be generated from the utilization of marine resources, including wave energy, tidal energy, river currents, ocean current energy, offshore wind, salinity gradient energy and thermal gradient sea energy [8]. Technically, sea energy is the energy that can be produced from the kinetic energy of the mechanical movement of seawater, potential energy from differences in sea level and seawater temperature. Marine energy can be converted into electrical energy by using technology that has developed rapidly in the international world. These energies are renewable energy because they come from sustainable natural processes [11].

Based on the review of various scientific reports, several potential sources of energy from the sea can be identified to support the electrical energy needs of coastal communities. The energy sources are wind, ocean currents, tidal currents, ocean waves, differences in salinity, and differences in seawater temperatures on the surface and on the seabed and sea plants that can be converted into biofuels. This resource is technically an alternative to conventional energy in meeting the electrical energy needs of the community which continues to increase along with population growth. For the maritime sector, marine energy provides hope especially for solving the energy problem in remote islands that have not been reached by electricity. The energies mentioned above are forms of renewable energy that can be produced from the use of marine resources. According to the results of a review of the report on the development of energy sources mentioned above [14]. Technically, the marine energies mentioned above can be converted from forms of kinetic energy, potential energy and the temperature difference in seawater. The potential use of sea energy that can be used technology to produce new electrical energy is limited to four types of energy, namely:

1. Sea wave electrical energy, which is converted from the kinetic power of the vertical movement of sea levels (ocean waves) through the parameters of height, length and wave period.
2. Tidal electrical energy, which is converted from the potential power of sea-level differences.
3. The electrical energy of ocean currents, which is converted from the kinetic power of the mass movement of seawater that passes through the strait due to tidal cycle movements.
4. Electric energy difference in temperature of seawater or OTEC (Ocean Thermal Energy Conversion), which is converted from the power contained in the difference in temperature of seawater on the surface and in the deep sea.

The potential of electricity generated from marine energy in Indonesia has been widely studied and calculated by various parties, one of which is a calculation issued by the Indonesian Ocean Energy Association [15]. These potentials are grouped into theoretical potentials, technical potentials, and practical potentials for types of marine energy conversion technologies namely tidal currents, ocean waves, and energy temperature differences in the ocean as shown in Figure 1.

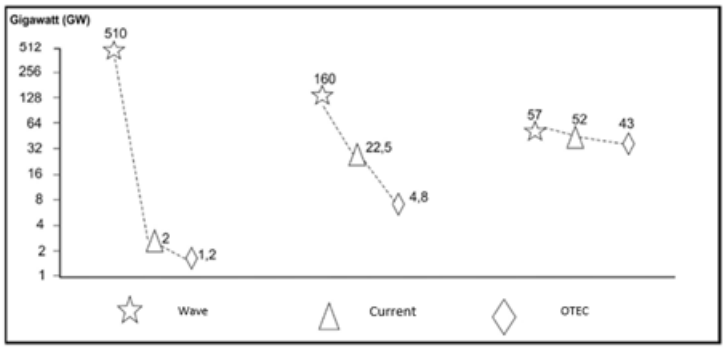

Figure 1. Potential Alternative Sources of Energy in the Maritime Sector

As shown in Figure 1, the maritime resource that has the most opportunity to be developed is the seawater temperature difference (OTEC) because its practical potential is highest compared to other marine energy sources. Based on data released by P3GL and ESDM, the potential of OTEC in Indonesian waters reaches 2.5 x 1023 Joules. With an efficiency of sea heat energy conversion of 3%, it can produce around 240,000 MW of power [9]. If seen from the natural conditions and geographical location of Indonesia which has many islands and straits, sea energy that has prospects to be developed is ocean current energy. Furthermore, the position of the Indonesian sea which lies between the Pacific Ocean and the Indian Ocean causes currents to move at high speeds. In addition to the large current strength, the Indonesian sea is also very rich in current energy sources tides which are expected to produce tidal current energy of 4.8 GW [12]. The four potential types of marine energy along with generating

capacity, potential locations and electricity needs are shown in Table 1.

Table 1. Maritime Sector Potential and Energy Types

DETAIL	RESOURCE ENERGY			
	WAVE	CURRENT	TIDAL	OTEC
Potency of Energy	1.200 MW	4.800 MW	6.000 MW	220.000 MW
Plant Capacity	0,5 - 2 MW	10 - 200 MW	10 - 200 MW	5 - 100 MW
Location	Small Island and Littoral Area	East Area	Bali - NTT	Small Island and Littoral Area
Electrical Requirement	100 kW - 1,5 mW	> 10 MW	1-20 MW	> 5 MW

Ocean energy from waves, currents, and differences in seawater temperature (OTEC) have the potential to produce electrical energy. Ocean wave energy is an energy that is produced from the movement of ocean waves towards the mainland and vice versa. Indonesia's vast sea area has great potential in producing electricity, but its utilization is not yet optimal. The advantage of this power plant is that it does not cause pollution because the driving source uses renewable natural energy, even though the installation and maintenance costs are expensive. To realize this, a deeper study needs to be done. Measurement and mapping of potential ocean currents have been carried out by the Center for Marine Geology Study and Development., while the energy potential from temperature differences is still in the process of being tested for eligibility by BPPT and Dharma Persada University. Energy difference in seawater temperature is the development of energy for the medium and long term by using OTEC technology which functions as a multipurpose such as for electricity, aquaculture businesses, a supply of fresh and mineral water, studies, and tourism [15]. OTEC power plants are used by utilizing the difference between surface water temperature and temperature in the sea so that it can produce electricity that can be enjoyed by households and businesses in the community economy.

2.2 PEST Analysis Method

PEST analysis is an analysis of business external environmental factors that include the political, economic, social and technological fields [17]. The PEST analysis model is carried out by collecting and describing information about external factors that have the potential to affect the business. PEST is a useful way or tool to summarize the external environment in business operations. PEST is used to assess the market of a business unit or organizational unit. The PEST analysis direction is a framework for assessing a situation, and assessing the strategy or position, the direction of the company, the marketing plan or idea. Where this analysis can be taken a new opportunity or threat to the company.

2.2.1 Factor PEST Analysis

These factors include the fields of Political, Economic, Social, Technological, Legal, and Environment.

a. Political

Political factors include the applicable law, government policies, and formal or informal rules in the corporate environment (Example: tax policies and local regulations).

b. Economic

Economic factors include all factors that affect the purchasing power of customers and affect the business climate of a company (Example: exchange rate standards, interest rates, and economic growth).

c. Social

Social factors include all factors that can affect the needs of customers and affect the size of the existing market share (Example: level of public education, level of population growth, social and work environment conditions).

d. Technological

Technological factors include all things that can help in facing business challenges and support the efficiency of a company's business processes (Example: discoveries and developments, costs and uses of technology, changes in science, and the impact of technological changes).

2.2.2. Benefits of PEST Analysis

PEST analysis has several benefits including:

a. It is a very useful tool in understanding the overall picture of the environment in which the business operates and the opportunities and threats that surround it. So that opportunities can be taken and minimize risks or threats.
b. It is a tool to understand all risks associated with the growth or decline in business, and also the position, potential and strategic direction for business and organizations.
c. It is a generic orientation tool to find out whether an organization in an environmental context with everything happening out there at the same time influences the organization.

2.2.3 Purpose of PEST Analysis

PEST analysis is a simple and effective tool for identifying which external forces might affect your business. This power needs to be identified because it can create an opportunity or a threat. Therefore the purpose of doing PEST is to:

a. Find out current external factors that can affect the organization
b. Identify external factors that might change in the future
c. Take advantage of opportunities or avoid threats from external factors

2.2.4 Results of PEST Analysis

The result of the PEST Analysis is an understanding of the whole picture of the company. This analysis can also be used to assess new market potential. The more negative forces that affect the market, the more difficult it is to do business in that market. Difficulties encountered in these markets can reduce the company's profit potential and limit the company's business movements in the market.

2.2.5 Variants of PEST Analysis

PEST analysis is the most common version of all variations of PEST created. The following are variations of the PEST analysis. There is an additional component in the analysis below because the company can easily identify the forces that affect its organization:

a. STEP = PEST in a more detailed approach
b. PESTEL = PEST + E (Environment) Environment + L (Legal/Law)
c. PESTELI = PESTEL + I (Industrial)
d. STEEP = PEST + E (Ethics)
e. SLEPT = PEST + Legal
f. STEEPLE = PEST + E (Environment) environment + L (legal) Law + E (Ethics)
g. STEEPLED = STEEPLE + D (Demographic)
h. PESTLIED = PEST + L (Legal/Law + I (International) + E (Environment) + D (demographic) demographics
i. LONGPEST = L (Local) + N (National) + G (Global Factors) + PEST.

2.3 Fuzzy MCDM Analysis Method

2.3.1 Concept of *Fuzzy* Theory

The concept of the fuzzy theory was initiated by Lotfi A. Zadeh in 1965 with his seminal paper "Fuzzy Sets" [7]. Before working with the fuzzy theory, Zadeh used control theory. He developed the concept of "state", which is the basic form of modern control theory. With fuzzy theory shows that all theories can be used as a basic concept of the fuzzy or continuous membership function. Broadly speaking, fuzzy theory can be classified into five main areas, namely:

a. Fuzzy Mathematics, where the concept of classical mathematics is expanded by changing the classical set with the fuzzy set;
b. Fuzzy Logic & Artificial Intelligence, where estimates for classical logic are introduced and expert systems are developed based on fuzzy information and thought estimates;
c. Fuzzy System, which includes fuzzy control and fuzzy approaches with signal processing and communication;
d. Uncertainty and Information, where differences from uncertainty are analyzed;
e. Fuzzy Decision Making, where consideration exists for optimization problems.

2.3.2 Membership Functions

The membership function is a curve that shows the mapping of data input points into the value of membership (often also called the degree of membership) which has an interval between 0 to 1. One way that can be used to obtain membership values is through a function approach. Several functions can be used:

a. Linear Representation

In linear representations, mapping the input to the degree of membership is drawn as a straight line. This form is the simplest and is a good choice for approaching a less clear concept. There are 2 states of linear fuzzy sets, the first is the increase in the set starts at the domain value that has a zero membership degree [0] moves right to the domain value that has a higher degree of membership.

Membership Function:

$$\mu[x] = \begin{cases} 0; & x \le a \\ (x-a)/(b-a); & a \le x \le b \\ 1; & x \ge b \end{cases}$$

Second, it is the opposite of the first. The straight line starts from the value of the domain with the highest degree of membership on the left, then moves down to the value of the domain that has a lower membership.

Membership Function:

$$\mu[x] = \begin{cases} (b-x)/(b-a); & a \le x \le b \\ 0; & x \ge b \end{cases}$$

b. Representation of Triangle Curves

A triangle curve is a combination of two lines (linear).

Membership function:

$$\mu[x] = \begin{cases} 0; & x \le a \text{ or } x \ge c \\ (x-a)/(b-a); & a \le x \le b \\ (c-x)/(c-b); & b \le x \le c \end{cases}$$

c. Representation of the Trapezoid Curve

Trapezoid curves are basically like triangles, it's just that there is a point that has a membership value of 1.

Membership function:

$$\mu[x] = \begin{cases} 0; & x \le a \text{ atau } x \ge d \\ (x-a)/(b-a); & a \le x \le b \\ 1; & b \le x \le c \\ (d-x)/(d-c); & c \le x \le d \end{cases}$$

2.3.3 Triangular Fuzzy Number (TFN)

In TFN, every single value (crisp) has a membership function consisting of three values, each of which represents the bottom value, middle value, and top value.

A = (a1, a2, a3)

The membership function for TFN in the picture above is as follows:

$$\mu[x] = \begin{cases} = 0 & \text{for } x < a_1 \\ = \frac{x-a_1}{a_2-a_1} & \text{for } a_1 < x < a_2 \\ = \frac{a_3-x}{a_3-a_2} & \text{for } a_2 < x < a_3 \end{cases}$$

2.3.4 Defuzzification Value

Defuzzification is a process of conversion and a quantity of fuzzy into a definite quantity, where the output and the fuzzy process can be a combination of logic from two or more fuzzy membership functions that are defined according to the universe of speech. Defuzzy input and process is a fuzzy set obtained from the composition of fuzzy rules, while the resulting output is a number in the fuzzy set domain. There are several methods of defuzzification commonly used are as follows:

a. Centroid Method (Center of Gravity / COG)
In this method, a crisp solution is obtained by taking the center point (z) of the fuzzy region.
b. Bisector Method In this method, a crisp solution is obtained by taking a value in the fuzzy domain that has a membership value of half of the total membership value in the fuzzy area.
c. Mean of Maximum (MOM) Method
In this method, a crisp solution is obtained by taking the average value of the domain that has a maximum membership value.
d. Largest of Maximum (LUM) Method
In this method, a crisp solution is obtained by taking the largest value from a domain that has a maximum membership value.
e. The Smallest Method of Maximum (SOM)
In this method, a crisp solution is obtained by taking the smallest value from the domain that has the maximum membership value.

2.3.5 Linguistic Variables

The linguistic variable is a variable that has a description in the form of fuzzy numbers and more generally a word that is represented by a fuzzy set. For example, descriptions of linguistic variables for temperature can be LOW, MEDIUM and HIGH where the description is expressed as a fuzzy value [16]. Like algebraic variables that use numbers as their values while linguistic variables use words or sentences as their values that form a set called "terms", each value of the "terms" is a fuzzy variable that is defined based on the base variable. Whereas the base variable defines the universe of speech for all fuzzy variables in the set of "terms".

2.3.5 Multiple Criteria Decision Making (MCDM)

Multi-Criteria Decision Making (MCDM) is a decision-making method consisting of theories, processes, and analytical methods for decision making that involve uncertainty, dynamics, and multi-criteria aspects of the decision. Multi-Criteria Decision Making (MCDM) is the terminology used in solving problems where the MCDM approach is expected to get the best alternative [13].

2.4 The Method of Research.

In this study, it is divided into 4 (four) main phases, namely the identification phase, the data collection phase, the analysis phase and the conclusion drawing phase. In the first phase of identification, identification of problems and research objectives is carried out. In the second phase of data collection, the primary data were collected from interviews and questionnaires, secondary data were obtained from literature studies in the form of books and journals. In the third phase, namely analysis. The first analysis is to make a mind mapping that is writing everything that is in the mind in the form of problems, objectives, aspects, steps, and methods in research. The method used for this research is Fuzzy MCDM to get the alternative value offered. In the Fuzzy MCDM method to determine alternative values, previously it must go through stages beginning with determining the criteria and alternative research in Figure 3. Conceptual Framework of Hierarki structure Fuzzy MCDM Analysis.

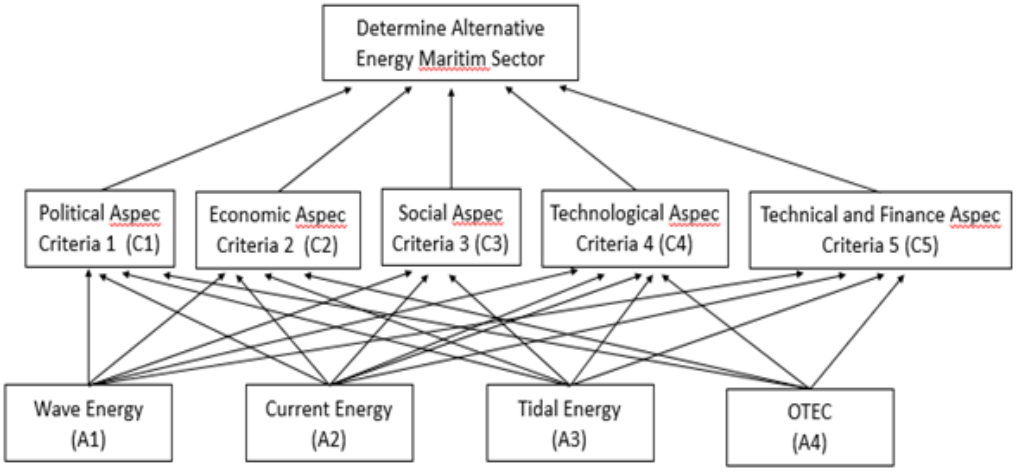

Figure 3. Conceptual Framework of Hierarki structure Fuzzy MCDM Analysis

In Figure 3. It can be explained that in determining alternative maritime potential energy resources developed are influenced by several aspects of the criteria. The criteria in this study can be divided into two, namely the criteria of internal factors and criteria of external factors. The internal factors criteria in the form of quantitative data used technical analysis and financial analysis. For the external factors criteria in the form of qualitative data, PEST analysis is used by mapping the political, economic, social and technological sectors in each alternative energy. Furthermore, from the existing criteria and alternatives, Fuzzy MCDM analysis is done by weighting and ranking to get the ranking value of each alternative. The ranking value obtained is used to determine the potential of alternative energy resources which can be considered by the government to be developed.

3. RESULT AND DISCUSSION

Based on the concept of fuzzy MCDM analysis, the relationship between research variables can be analyzed using the influence diagram, see Figure 4.

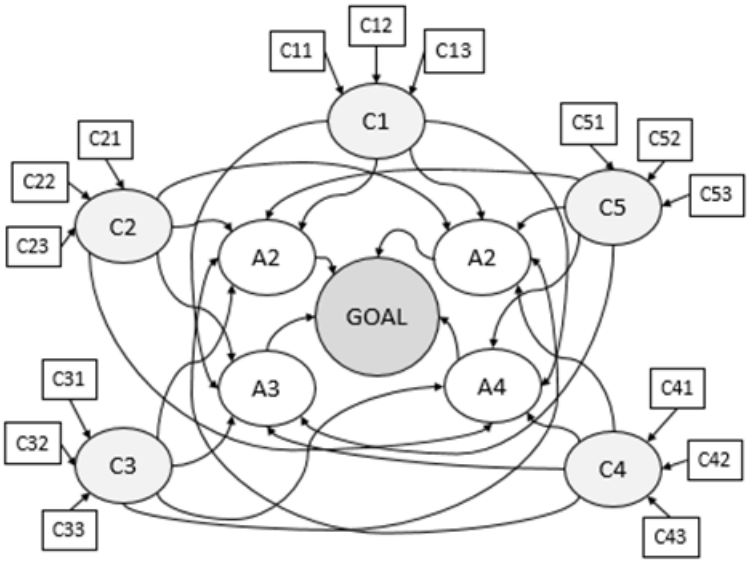

Figure 4. Influence Diagram Between Variables

In figure 4 to achieve the goal, namely the selection of alternative energy resources, maritime potential A_1, A_2, A_3, and A_4, it is understood that each alternative is influenced by the criteria of C_1, C_2, C_3, C_4, and C_5. Each criterion is influenced by sub-criteria $C_{1.1}$, $C_{1.2}$, $C_{1.3}$, $C_{2.1}$, $C_{2.2}$, $C_{2.3}$, $C_{3.1}$, $C_{3.2}$, $C_{3.3}$, $C_{4.1}$, $C_{4.2}$, $C_{4.2}$, $C_{5.1}$, $C_{5.2}$, and $C_{5.3}$. Criteria can be determined by technical analysis and financial analysis for internal factors (C_1), and PEST analysis (Politics, Economy, Social, and Technology) for external factors (C_2, C_3, C_4, and C_5).

Criteria for internal factors, technical and financial aspects can be broken down as follows:
a. Investment costs ($C_{1.1}$)
b. Electrical energy capacity ($C_{1.2}$)
c. Age of power plant ($C_{1.3}$)
Criteria for external factors of political aspects can be broken down as follows:
a. Government policy ($C_{2.1}$)
b. Statutory and regulations ($C_{2.2}$)
c. Political stability ($C_{2.3}$)
Criteria for external factors in economic aspects can be broken down as follows:
a. Inflation Rate ($C_{3.1}$)
b. Interest rate ($C_{3.2}$)
c. Currency Exchange rate stability ($C_{3.3}$)
Criteria for external factors of social aspects can be broken down as follows:
a. Culture of the surrounding peoples ($C_{4.1}$)
b. The attitude of the surrounding peoples ($C_{4.2}$)
c. Peoples mindset ($C_{4.3}$)
Criteria for external factors of technological aspects can be broken down as follows:
a. Global technological developments ($C_{5.1}$)
b. Transfer of technology from foreign countries ($C_{5.2}$)
c. Availability of supporting technology in the region ($C_{5.3}$)

After the criteria variable has been obtained, the analysis of determining the alternative energy resources of the maritime sector is continued with the fuzzy MCDM analysis. The steps taken are:
a. Determine the weighting of qualitative criteria assessments
b. Determine the rating of each alternative energy
c. Determine Fuzzy Numbers
d. Determine the aggregate weights for each qualitative criteria
e. Calculate the preference value of each alternative-qualitative
f. Calculate fuzzy index values for each alternative-qualitative
g. Defuzzification
h. Calculate the ranking value of each alternative-qualitative
i. Calculate the ranking value of each alternative-quantitative
j. Get the total ranking value of each alternative energy
k. Choose the best alternative based on the ranking value

4. CONCLUSION.

Based on the concepts offered, research on the potential of alternative energy resources in the maritime sector with the fuzzy MCDM (Multi-Criteria Decision Making) method is possible to develop. The results of this study are conceptual and only draft. This research can be continued so that the direction of the calculation of the relationship between variables can be in more detail to obtain an alternative ranking of energy. From the results of the ranking of alternative energy rankings, the results can be used for consideration by the government in determining energy sector policies where the current state of the energy crisis starts because fossil energy continues to run low.

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