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A PREFERENCE ANALYSIS OF RENEWABLE ENERGY ALTERNATIVES IN MALAYSIA USING FUZZY VIKOR METHOD

(Analisis Keutamaan bagi Tenaga Boleh Diperbaharui di Malaysia Menggunakan Kaedah VIKOR Kabur)

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ABSTRACT

In Malaysia, the main consumed energy is the fossil fuel. As the population continues to increase and the fossil fuels begin to deplete rapidly, it may not be possible to depend solely on fossil fuel. A feasible alternative should be sought to replace the dependency of the fossil fuel. In this paper, an evaluation is made on the experts' preference of the type of eco-friendly renewable energy that is suitable to be used in Malaysia between biomass, solar, hydro or hybrid energy using the fuzzy VIKOR method. Since the evaluation considers subjective element that involves human perceptions and knowledge experts, the Fuzzy VIKOR method is considered to be an appropriate choice. The Fuzzy VIKOR method has the ability to deal with multi-conflicting or non-commensurable criteria in the ranking and selecting the alternatives. The evaluation is based on four main criteria which are Efficiency, Operation, Land Use and Job Creation of each alternative. It is found that the main concern of the renewable energy choice is on its efficiency and the hydro energy is the most preferred alternative energy to be used in Malaysia.

Keywords: fossil fuel; renewable energy; fuzzy VIKOR

ABSTRAK

Di Malaysia, sumber utama tenaga yang diguna pakai adalah bahan api fosil. Apabila populasi terus berkembang dan bahan api fosil mula berkurangan dengan cepat, adalah tidak mungkin untuk hanya bergantung kepada bahan api fosil. Satu alternatif yang boleh digunakan harus dicari bagi menggantikan pergantungan bahan bakar fosil. Dalam makalah ini, penilaian dibuat oleh pakar mengenai keutamaan jenis tenaga boleh diperbaharui yang mesra alam yang sesuai digunakan di Malaysia, iaitu di antara tenaga biomas, solar, hidro atau tenaga hibrid menggunakan kaedah VIKOR kabur. Oleh kerana penilaian melibatkan unsur subjektif yang merangkumi persepsi manusia dan pakar pengetahuan, kaedah VIKOR kabur merupakan pilihan yang sesuai. Kaedah VIKOR kabur mempunyai keupayaan untuk menangani kriterium berbilang bertentangan atau tidak sepadan dalam pangkat dan pemilihan alternatif. Penilaian adalah berdasarkan empat kriterium utama, iaitu Kecekapan, Operasi, Penggunaan Tanah dan Penciptaan Pekerjaan bagi setiap alternatif. Didapati bahawa kriterium utama dalam pemilihan tenaga boleh diperbaharui adalah pada kecekapannya dan tenaga hidro merupakan pilihan tenaga boleh diperbaharui untuk digunakan di Malaysia.

Kata kunci: bahan api fosil; tenaga diperbaharui; VIKOR kabur

1. Introduction

In the past decade, Malaysia experienced an almost 20 percent increase in energy in the year 2000 to 2009 (Leung *et al*. 2014). Malaysia relies too much on fossil fuel to produce energy even though there are plenty of other resources of renewable energy. In 2009, fossil fuel such

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as natural gas, oil and coal are used to generate almost 94.5% of electricity (Shafie *et al.* 2011). Eventually fossil fuels are depleting and becoming more expensive and will consequently Discharge Greenhouse Gases (GHG) and other types of pollutants (Ong *et al.* 2012).

The selection of renewable energy resources involved the consideration of multiple qualitative and quantitative factors. Due to these complex factors, multi criteria decision making analysis is a useful method in renewable energy selection process. VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje), which is also called as the Compromise Ranking Method, is a practical approach in multiple criteria decision making process. Because of the vagueness and indeterminate information, as well as preference from different individuals, it is necessary to consider multi criteria decision making (MCDM) in solving the problems in uncertain condition. Therefore, the fuzzy set theory which consists of assumption that human feelings are linguistic variables, is an appropriate methodology. The combined fuzzy set theory and VIKOR method is widely used in various fields including in renewable energy selection process (Wang *et al.* 2016).

Malaysia formulated the National Green Technology Policy in April 2009 mainly to emphasize 'clean and green' as a new technology for economic growth and to promote the efficient usage of renewable energy resources. Some vast renewable energy resources available in Malaysia are solar, biomass, hydro and hybrid. Biomass energy is widely used for both industrialized and developing countries. Biomass originates from organic matter and is related to any woody material from plant that stores energy through photosynthesis (Ong *et al.* 2012; Rosnazri *et al.* 2012). Biomass is an energy source that can be easily obtainable any time from various sources (Ozturk *et al.* 2017). Solar, the most common and well known energy, is the transformation of sunlight into electricity through the use of solar cell installed in a solar panel. The solar energy is clean, cost-effective and sustainable energy source. It will sustain and compete with fossil-fuel power generation in the next ten years (Reddy *et al.* 2013). Hydro power can be produced from waves, tides and the natural flow of water. Based on Nor Fadilah *et al.* (2017), Malaysia is one of the suitable countries that can generate power from hydro because it has high rain volume per year and plenty of water sources from hundreds of rivers. The energy security and environment impact are two main reasons to search for alternative energy. The non-renewable sources such as fossil fuel and natural gas will deplete and also harm the environment. Thus, Malaysia needs to take fast action to realize the future prospective of renewable energy such as solar, biomass and others to keep the eco-system fresh and clean.

2. Decision Making in Renewable Energy

The selection of various renewable energy resources is an industrious task. The complexity of making the selection of the multi criteria which includes social, economic, technological and environmental factors, involves vagueness in the selection process. Due to this, the fuzzy set theory which proposed that human perceptions are linguistic variables, is an appropriate methodology (Wang *et al.* 2016).

Some methods of decision making that incorporated fuzzy set theory to deal with uncertainties are introduced to address MCDM issues. These methods include Fuzzy TOPSIS (Technique for Order Performance by Similarity to Ideal Solution), Fuzzy AHP (Analytic Hierarchy Process), Fuzzy ANP (Analytical Network Process), Fuzzy DEMATEL (Decision Making Trial and Evaluation Laboratory Model) and Fuzzy VIKOR (Mohamad *et al.* 2015; Nur Ain *et al.* 2019; Raja Nazim *et al.* 2013; Suriana *et al.* 2013).

MCDM literature for sustainable energy and the methods for criteria weights are classified into three types: subjective weights, objective weights and combination weights methods (Wang *et al*. 2016). The Analytic Hierarchy Process (AHP) was applied in Stein (2013) to rank various electricity generation technologies to compare from financial, technical, socioeconomic-political and environmental aspects. The graph theory and AHP were integrated by Lanjewar *et al.* (2016) to evaluate and rank the conventional and renewable energy systems. Fuzzy VIKOR & AHP methodology were utilized by Kaya and Kahraman (2010) to compare the following renewable energy alternatives: solar, wind, geothermal, hydraulic and biomass using a set of ten criteria. However, San Cristóbal (2011) employed the VIKOR method for renewable energy selection. These include wind power, solar, biomass and hydroelectric which are compared with the identified criteria including operating hours, power, useful life and investment ratio. An integrated fuzzy VIKOR-AHP method is also aimed at identifying potential areas in India (Asif *et al.* 2019). Abbas *et al.* (2015) presented some MCDM methodologies that has been used in the energy systems. Six major MCDM methods were compared: i) AHP and fuzzy AHP, ii) PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation), iii) TOPSIS and fuzzy TOPSIS, iv) ANP and VIKOR, v) integrated methods and vi) other methods.

The advantage of using Fuzzy VIKOR method compared to others is because there is no risk of loss of information between the alternatives and another advantage compared to fuzzy TOPSIS is that it derives the compromise solution(s) which consider not only the fuzzy best value but also the fuzzy worst value as well. The main objective of this study is to use the fuzzy VIKOR method to select and rank the most preferred renewable energy to be used in Malaysia as the best alternative based on the four criteria taken into consideration.

3. Methodology

Some definitions related to the fuzzy set and triangular fuzzy numbers are given as follows:

Definition 3.1 (Bojadziev & Bojadziev 1995). A fuzzy set is defined by a set of ordered pairs, such that $A=\left\{\left(x,\mu_{\tilde{A}}(x)\right) \middle| \, x \in A, \mu_{\tilde{A}}(x) \in [0,1]\right\}$, where $\mu_{\tilde{A}}(x)$ is a function called membership function; $\mu_{\tilde{A}}(x)$ specifies the degree to which any element *x* in *A* belongs to the fuzzy set *A*.

Definition 3.2 (Li *et al.* 2015). A triangular fuzzy number (TFN) $\tilde{A}=(a_1,a_2,a_3)$ is a fuzzy set defined by a membership function $\mu_{\tilde{A}}(x): \Re \to [0,1]$ where

$$\mu_{\tilde{A}}(x)=\begin{cases} \dfrac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ \dfrac{x-a_3}{a_2-a_3}, & a_2 \le x \le a_3 \\ 0 & otherwise \end{cases},$$

such that $\tilde{A}=(a_1, a_2, a_3) \in \Re$, $a_1 \le a_2 \le a_3$. In particular, $\tilde{A}$ is a singleton if $a_1 = a_2 = a_3$.

Definition 3.3 (Chen & Hsieh 1999). Operations on two TFNs $\tilde{A}=(a_1,a_2,a_3)$ and $\tilde{B}=(b_1,b_2,b_3)$:

(1) addition: $\left(\tilde{A} \oplus \tilde{B}\right)=\left(a_1+b_1, a_2+b_2, a_3+b_3\right)$,

(2) multiplication: $\left(\tilde{A} \otimes \tilde{B}\right)=\left(a_1 b_1, a_2 b_2, a_3 b_3\right)$,

(3) subtraction: $\left(\tilde{A} - \tilde{B}\right)=\left(a_1-b_3, a_2-b_2, a_3-b_1\right)$.

4. Fuzzy VIKOR

In this section, the fuzzy VIKOR procedure will be used in the evaluation of the renewable energy selection.

Step 1: Form a group of decision makers (*D*) and determine the evaluation criteria (*C*) and alternatives (*A*).

Step 2: Identify suitable linguistic terms for the importance weight of criteria, and the rating for alternatives with regard to each criterion. This can be observed in Table 1.

Table 1: Linguistic terms for criteria weights and rating of alternatives

Criteria Weight	Fuzzy Number	Ratings of Alternatives	Fuzzy Number
Very low (VL)	(0.0, 0.0, 0.1)	Very Poor (VP)	(0.0, 0.0, 0.1)
Low (L)	(0.0, 0.1, 0.3)	Poor (P)	(0.0, 0.1, 0.3)
Medium Low (ML)	(0.1, 0.3, 0.5)	Medium Poor (MP)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)	Fair (F)	(0.3, 0.5, 0.7)
Medium High (MH)	(0.5, 0.7, 0.9)	Medium Good (MG)	(0.5, 0.7, 0.9)
High (H)	(0.7, 0.9, 1.0)	Good (G)	(0.7, 0.9, 1.0)
Very High (VH)	(0.9, 1.0, 1.0)	Very Good (VG)	(0.9, 1.0, 1.0)

Step 3: Obtain the aggregated fuzzy weight of criteria, and aggregated fuzzy rating of alternatives by extracting the decision maker's opinion. The importance weight of each criterion and rating of each alternative can be calculated by Eqs. (1) and (2), with *k* as the number of decision makers:

$$\tilde{w}_j = \frac{1}{k}\left[\tilde{w}_j^1 + \tilde{w}_j^2 + \ldots + \tilde{w}_j^k\right], \quad (1)$$

$$\tilde{x}_{ij} = \frac{1}{k}\left[\tilde{x}_{ij}^1 + \tilde{x}_{ij}^2 + \ldots + \tilde{x}_{ij}^k\right]. \quad (2)$$

Step 4: Construct a fuzzy decision matrix $\tilde{D}$ and the weighted normalized fuzzy decision matrix.

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix}, i = 1,2,\ldots,m; \quad j = 1,2,\ldots,n \,, \quad (3)$$

$$\tilde{W} = \left[\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n\right], \; i = 1,2,\ldots,m; \quad j = 1,2,\ldots,n \,, \quad (4)$$

where $\tilde{x}_{ij}$ = the rating of alternative A_i with regard to C_j,
$\tilde{w}_j$ = the significance weight of the j^{th} criterion holds.

Step 5: Determine the fuzzy best value (FBV), denoted as $\tilde{f}_j^*$, and fuzzy worst value (FWV), denoted as $\tilde{f}_j^-$.

$$\tilde{f}_j^* = max_i \, \tilde{x}_{ij} \,, \qquad \tilde{f}_j^- = min_i \, \tilde{x}_{ij} \,. \quad (5)$$

Step 6: Calculate the values of $\tilde{S}_i$ and $\tilde{R}_i$.

$$\tilde{S}_i = \frac{\sum_{j=1}^{n} \tilde{w}_j \left(\tilde{f}_j^* - \tilde{x}_{ij}\right)}{\left(\tilde{f}_j^* - \tilde{f}_j^-\right)} \quad , \tag{6}$$

$$\tilde{R}_i = max_j \left[\tilde{w}_j \left(\tilde{f}_j^* - \tilde{x}_{ij}\right) / \left(\tilde{f}_j^* - \tilde{f}_j^-\right)\right] , \tag{7}$$

where $\tilde{S}_i = A_i$ with respect to all criteria calculated by the sum of the distance for the fuzzy best value, $\tilde{R}_i = A_i$ with respect to the j^{th} criterion, calculated by maximum distance of fuzzy worst value.

Step 7: State the values of $\tilde{S}^*, \tilde{S}^-, \tilde{R}^*$ and $\tilde{R}^-$.

$$\tilde{S}^* = min_i\ \tilde{S}_i , \quad \tilde{S}^- = max_i\ \tilde{S}_i , \quad \tilde{R}^* = min_i\ \tilde{R}_i , \quad \tilde{R}^- = max_i\ \tilde{R}_i . \tag{8}$$

Step 8: Defuzzify the triangular fuzzy number $\tilde{Q}_i$ and rate the alternatives by the index Q_i by using Eq. (9).

$$\tilde{Q}_i = \frac{v\left(\tilde{S}_i - \tilde{S}^*\right)}{\tilde{S}^- - \tilde{S}^*} + (1-v)\frac{\left(\tilde{R}_i - \tilde{R}^*\right)}{\left(\tilde{R}^- - \tilde{R}^*\right)} \quad , \tag{9}$$

where *v* is often set to be 0.5 (Nordianah 2018).

The graded mean integration (Yong 2006) is used for the defuzzification process. A fuzzy number $\tilde{Q}_i = \left(\tilde{Q}_{i1}, \tilde{Q}_{i2}, \tilde{Q}_{i3}\right)$ is converted into an exact number by utilizing the following equation:

$$U_T \tilde{Q}_i = \frac{\tilde{Q}_{i1} + \tilde{Q}_{i2} + \tilde{Q}_{i3}}{3} \quad . \tag{10}$$

By merging the right and left utilities, the crisp value can be obtained. The list Q_i implicit the detachment estimate of A_i from the top alternative. That is, the smaller the value, the preferable the alternative.

Step 9: Determine the best compromise solution. Assuming the two requirements given below are satisfied, we can determine the best option (a') by ranking the index *Q* as follows:

[Condition 1]: Reasonable advantage.

$$Q(a'') - Q(a') \geq DQ \tag{11}$$
$$DQ = \frac{1}{m-1}$$

[Condition 2]: Acceptable stability.

Under this requirement, the alternative *a'* must be ranked the first with the minimum of $S(a')$ or/and $R(a')$.
If one of these conditions is not acceptable, we can determine a compromise solution:

(1) Alternatives *a'* and *a''* if condition 2 is not satisfied, or
(2) Alternatives *a'*, *a''*, …, $a^{(m)}$ if condition 1 is not satisfied: a^m can be calculated by the equation $Q(a^m) - Q(a') < DQ$ for maximum *m*.

Step 10: Determine the best alternative. The minimum of Q_i is the best alternative $Q(a')$.

5. Renewable Energy Resources Selection for Malaysia Based on Fuzzy VIKOR

In this research, the following process was implemented for the selection of preferable renewable energy using fuzzy VIKOR method.

Step 1: A group of 4 experts was formed as decision makers (*D*). These individuals were selected based on their experience in researches involving renewable energies in Malaysia. The evaluation criteria which are Efficiency C_1, Operation and Maintenance Costs C_2, Land Use C_3 and Job Creation C_4 meanwhile the energy alternatives which are Biomass A_1, Solar A_2, Hydro A_3, and Hybrid A_4 were determined.

Step 2: The suitable linguistic terms from Table 1 for the importance of criteria weight, and the rating for alternatives were identified with regard to each criterion.

The weights of criteria by the decision makers are presented in Table 2.

Table 2: Importance weights of criteria C_j by decision makers D_k

C_1 (Efficiency)				C_2 (Operation)				C_3 (Land Use)				C_4 (Job Creation)			
D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4
H	H	VH	VH	H	MH	H	H	MH	H	H	M	MH	H	MH	ML

Step 3: The aggregated fuzzy weight of criteria, and aggregated fuzzy rating of alternatives were obtained by extracting the decision makers' opinion. The rating of each alternative can be calculated by Eqs. (1) and (2), with *k* as the number of decision makers as in Table 3.

Table 3: Rating of alternatives A_i, based on criteria C_j by decision maker D_k

	A_1				A_2				A_3				A_4			
	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4
C_1	MG	MP	VG	G	G	G	G	VG	G	VG	VG	VG	MG	F	VG	G
C_2	F	F	G	G	F	MG	MG	G	MG	VG	VG	G	MG	MG	G	G
C_3	F	MG	G	G	MP	VG	F	F	MG	VG	VG	F	MG	MG	G	F
C_4	MG	MG	G	F	MG	VG	F	MP	F	VG	G	F	MG	MG	G	F

Step 4: The fuzzy decision matrix D and the weighted normalized fuzzy decision matrix are constructed as in Table 4 and Table 5, by using Eqs. (3) and (4).

Table 4: Fuzzy weight of criteria

Criteria	Weight
C_1	(0.8, 0.95, 1.0)
C_2	(0.65, 0.85, 0.975)
C_3	(0.55, 0.75, 0.9)
C_4	(0.45, 0.65, 0.825)

Table 5: Weighted normalized fuzzy decision matrix

	A_1	A_2	A_3	A_4
C_1	(0.550, 0.725, 0.850)	(0.750, 0.925, 1.000)	(0.850, 0.975, 1.000)	(0.600, 0.775, 0.900)
C_2	(0.500, 0.700, 0.850)	(0.500, 0.700, 0.875)	(0.750, 0.900, 0.975)	(0.600, 0.800, 0.950)
C_3	(0.550, 0.750, 0.900)	(0.400, 0.575, 0.725)	(0.650, 0.800, 0.900)	(0.500, 0.700, 0.875)
C_4	(0.500, 0.700, 0.875)	(0.450, 0.625, 0.775)	(0.550, 0.725, 0.850)	(0.500, 0.700, 0.875)

Step 5: The fuzzy best value (FBV), $\tilde{f}_j^*$, and fuzzy worst value (FWV), $\tilde{f}_j^-$, were formed. By using Eq. (5), the aggregated fuzzy decision matrix was investigated, the values of Z^* and f_j are listed in Table 6.

Table 6: Fuzzy Best Value (FBV) and Fuzzy Worst Value (FWV)

	f_i^*	f_i^-
C_1	(0.8500, 0.9750, 1.0000)	(0.5500, 0.7250, 0.8500)
C_2	(0.7500, 0.9000, 0.9750)	(0.5000, 0.7000, 0.8500)
C_3	(0.6500, 0.8000, 0.9000)	(0.4000, 0.5750, 0.7250)
C_4	(0.5500, 0.7250, 0.8750)	(0.4500, 0.6250, 0.7750)

Step 6: The values $\tilde{S}_i$ and $\tilde{R}_i$ are calculated respectively as shown in Table 7 by using Eqs. (6) and (7).

Table 7: List $\tilde{S}_i$ and $\tilde{R}_i$

	$\tilde{S}_i$	$\tilde{R}_i$
A_1	(1.8950, 2.1292, 1.9750)	(0.8000, 0.9500, 1.0000)
A_2	(1.9167, 2.4400, 2.5050)	(0.6500, 0.8500, 0.9000)
A_3	(0.0000, 0.0000, 0.0000)	(0.0000, 0.0000, 0.2063)
A_4	(1.6117, 2.2080, 0.9902)	(0.6667, 0.7600, 0.6667)

Step 7: Using Eq. (8), the $\tilde{S}^*, \tilde{S}^-, \tilde{R}^*$ and $\tilde{R}^-$ are determined and depicted in Table 8.

Table 8: Values of $\tilde{S}^*, \tilde{S}^-, \tilde{R}^*$ and $\tilde{R}^-$

$\tilde{S}^*$	(0.0000, 0.0000, 0.0000)
$\tilde{S}^-$	(1.9167, 2.4400, 2.5050)
$\tilde{R}^*$	(0.0000, 0.0000, 0.2063)
$\tilde{R}^-$	(0.8000, 0.9500, 1.0000)

Step 8: Calculate the Q_i for each alternative with Eq. (9), and the result is shown in Table 9.

For A_1,

$$\tilde{Q}_i = \frac{v\left(\tilde{S}_i - \tilde{S}^*\right)}{\tilde{S}^- - \tilde{S}^*} + (1-v)\frac{\left(\tilde{R}_i - \tilde{R}^*\right)}{\left(\tilde{R}^- - \tilde{R}^*\right)}$$

$$= \frac{0.5(1.8950 - 0.0000)}{1.9167 - 0.0000} + (1-0.5)\frac{(0.8000 - 0.0000)}{(0.8000 - 0.0000)}$$

$$= 0.9943$$

Table 9: List $\tilde{Q}_i$, Q_i and rank for alternatives

Candidates	$\tilde{Q}_i$	$U_T\left(\tilde{Q}_i\right)$	Rank
A_1	(0.9943, 0.9363, 0.8942)	0.9416	4
A_2	(0.9063, 0.9474, 0.9370)	0.9302	3
A_3	(0.0000, 0.0000, 0.0000)	0.0000	1
A_4	(0.8371, 0.8526, 0.4877)	0.7258	2

Step 9: Using the double conditions, determine a compromise solution (a') by the index Q .

[Condition 1] Acceptable advantage.

By Eq. (11), $Q(a'') - Q(a') = 0.7258 - 0.0000 = 0.7258 > 0.3333$,
and $Q(a''') - Q(a') = 0.9302 - 0.0000 = 0.9302 > 0.3333$.

[Condition 2] Reasonable range in decision making, as shown in Table 10.

Table 10: Reasonable range in decision making

Rank by Q_i	$A_3 \succ A_4 \succ A_2 \succ A_1$
Rank by S_i	$A_3 \succ A_4 \succ A_1 \succ A_2$
Rank by R_i	$A_3 \succ A_4 \succ A_2 \succ A_1$

The result shows that Conditions 1 and 2 are satisfied. So, A_3 is the solution.

Step 10: The best alternative is indicated by the minimum value of $Q(a')$. It is suggested that the compromise solution is A_3 owing to its closeness to the best alternative.

6. Result and Discussion

The process of selecting the best renewable energy resources was a complex and difficult process due to vagueness and subjectivity in the selection process as well as various factors to consider simultaneously. In this study, four decision makers who were experts in this field were chosen to do the selection process. The four main renewable energy resources that are possible to conduct in Malaysia are, biomass energy, solar energy, hydro energy and hybrid energy. The criteria taken into consideration to choose the renewable energy are efficiency, operation and maintenance cost, land utilization and job creation. Using Fuzzy VIKOR method, the best solution was ranked based on the answers from the experts.

The results obtained indicate that hydro energy is the most preferred renewable energy among the experts. According to the values of Q_i, the compromise solution of the renewable energy is hydro energy (A_3), followed by hybrid energy (A_4), solar energy (A_2) and biomass energy (A_1). Results of the compromise solution are shown in Table 9. Ranking of the criteria indicates that efficiency is most considered when choosing the best alternative. This is followed by operation and maintenance cost, land utilization and job creation as in Table 4.

Hydrological analysis and hydrological method are used to evaluate the hydropower potential. Malaysia can generate power from hydro as it has high rain volume per year. In Malaysia, implementation of small scale hydro power technologies is more dominant than large scale hydro power plants, as oppose to large scale hydropower plants that have negative impact to the nature. From this reason and the calculation made by Fuzzy VIKOR, hydropower is the most suitable renewable energy that should be used in Malaysia.

7. Conclusion

Selecting the best renewable energy resource is a complex procedure when considering various factors simultaneously. Thus, due to the uncertainty and vagueness in the selection process, which includes human perceptions and knowledge experts, the Fuzzy VIKOR method is an appropriate choice. This method can deal with multiple attributes problems in the ranking and selecting of the alternatives.

An evaluation of biomass energy, solar energy, hydro energy and hybrid energy were carried out by the energy experts with respect to four main criteria which includes efficiency, operation, land use and job creation. In addition, these four assessment criteria were backed by literature. Using the fuzzy VIKOR method, it is found that the hydro energy is the preferred alternative among other renewable energy resources in Malaysia, followed by hybrid energy, solar energy and biomass energy. The dependency on the natural sources of energy has to be minimized as the non-renewable will soon be depleted. A proper strategic planning needs to be tabled out and implemented for the usage of renewable energy to complement and soon over take the consumption of the fossil fuel.

Last but not least, the investment on hydro energy technologies prior to the other renewable energy alternatives is highly recommended that would significantly improve the investment benefits and promote the positive continual for the society.

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