Development of priority decision for renewable energy potential using analytical hierarchy process and geographical information system method

by Meita Rumbayan 24

Submission date: 12-Mar-2019 07:24AM (UTC+0700)
Submission ID: 1091710148
File name: DEVELOPMENT_OF_PRIORITY_DECISION.pdf (406.29K)
Word count: 4907
Character count: 24381

Development of priority decision for renewable energy potential using analytical hierarchy process and geographical information system method

Ken Nagasaka

Department of Electrical and Electronic Engineering,
Tokyo University of Agriculture and Technology,
2-24-16 Nakamachi, Koganei-shi, Tokyo 184-8588, Japan
E-mail: bahman@cc.tuat.ac.jp

Meita Rumbayan*

Department of Electrical Engineering,
Sam Ratulangi University,
Manado 95000, Indonesia
E-mail:meitarumbayan@yahoo.com
*Corresponding author

Abstract: The purpose of this research is to develop decision making method for site selection and to rank the priority of renewable energy potential development site using analytical hierarchy process (AHP) and geographical information system (GIS) in Indonesia. This study identifies the energy alternative that focusing on solar, wind and geothermal based on previous work by authors as continuity study. The AHP model is built to identify the weight of criteria for two hierarchies. The weight has been used as input for spatial analysis in GIS method. The resources map is generated by overlaying solar irradiation map, wind speed map and geothermal potential map with spatial analysis tool in GIS environment. The result shows that geothermal is the best criteria, followed by solar and wind alternatives with weight value of 0.72, 0.22, and 0.06 respectively. Resource map generated identifies the high, moderate and low suitability site to rank the priority decision of renewable energy development for Indonesia. Based on the result, the site selection of ten locations can be found to give the recommendation for priority development of renewable energy. In addition, the potential of renewable energy in term of technical potential, economic potential and carbon dioxide reduction potential are calculated based on assumption and reference by considering the application of renewable energy technology. The proposed methodology is useful to identify the renewable energy resources site for development priority. The method can be used to achieve the similar objectives for other country.

Keywords: analytical hierarchy process; AHP; geographical information system; GIS; decision making; renewable energy.

Reference to this paper should be made as follows: Nagasaka, K. and Rumbayan, M. (2013) 'Development of priority decision for renewable energy potential using analytical hierarchy process and geographical information system method', *Int. J. Advanced Mechatronic Systems*, Vol. 5, No. 4, pp.270–278.

Biographical notes: Ken Nagasaka received his PhD in Electrical Engineering from Tokyo Metropolitan University in 1990. He became Chief Researcher at CSD Company, Tokyo (1990–1991). He became a Visiting Professor at University of Manitoba, Winnipeg, Canada (1991–1994). He worked as a Scientist at Central Research Institute of Electric Power Industry, Tokyo (1994–1998). He became an Associate Professor at the Department of Electrical Engineering of Tokyo Metropolitan University (1995–1998). Since 1998, he taught and researched at the Graduate School of Engineering, Tokyo University of Agriculture and Technology. Currently, he is a Professor of Tokyo University of Agriculture and Technology. He has published more than 600 papers in the area of power systems and renewable energies.

Meita Rumbayan received her Bachelor of Engineering in Electrical Engineering from Samratulangi University in 1998, Master of Engineering in Energy Technology from the Asian Institute of Technology, Thailand in 2007 and Doctor of Engineering in Department of Electronic and Informatics from the Tokyo University of Agriculture and Technology in 2013. Currently, she is working as a Lecturer in Department of Electrical Engineering, Sam Ratulangi University in Manado, Indonesia. Her research interests include renewable energy and electrical engineering.

This paper is a revised and expanded version of a paper entitled 'Priorization decision for renewable energy development using analytic hierarchy process and geographic information system' presented in 2012 International Conference on Advanced Mechatronic Systems (ICAMechS 2012), Tokyo, Japan, 18–21 September, 2012.

1 Introduction

At present, we are making efforts on the study for spreading the environment-friendly renewable energy. Indonesia's energy status and commitment to develop renewable energy have been growing and setting up for the future sustainable development. When selecting which sites are suitable for developing renewable energy in Indonesia, the renewable energy resource map is needed. The country of Indonesia consists of total area 1,919,440 km^2 (1,826,440 km^2 of inland and 93,000 km^2 of inland water).

Indonesia consists of many islands and is the world's largest archipelagic state, which is situated at 95° to 141° of east longitude and latitude 6° north to latitude 11° south. It consists of many islands, whereas has five islands biggest namely Sumatera, Kalimantan, Java, Sulawesi, Papua and other small islands such as Bali, Ambon, Lombok, Nusa Tenggara, as well as thousands of tiny island where spread out surrounding the mainland. Its population is over 238 million people.

The need of energy due to population growth is increasing year by year that is why Indonesia is facing energy power shortage. In other hand, Indonesia has many energy resources which are abundant for source of power generation. In order to make decision for energy development among the site selection, it is essential to generate the resource map site suitable location to prioritise for renewable energy development in this wide country.

Due to the availability of data, this study is focusing in theoretical potential as a criterion based on previous study by authors in solar irradiation, wind speed and geothermal resources. Therefore this study is a development for continuities study in the area of renewable energy potential analysis in Indonesia.

The first objective is to develop decision making of site prioritisation for renewable energy development in Indonesia; the second objective is to generate the resource map based on decision making method in GIS technology.

The next stage is to analysis the potential of renewable energy in site selections based on result and data available from the previous stage in this dissertation for each renewable energy sources, i.e., solar energy, wind energy and geothermal energy. The potential of renewable energy in term of technical potential, economic potential and carbon dioxide reduction potential are described as follows:

1 *Technical potential*

   This analysis refers to theoretical potential based on data available and technical potential based on the technology chosen of renewable energy exploitation.

2 *Economic potential*

   This analysis about economic potential is done based on reference of renewable energy cost for each type of renewable energy generation.

3 *Carbon dioxide reduction potential*

   This analysis is done based on assumption that emission factor equal to 1.02 kgCO_2 per kWh can be reduced if the renewable energy generated of electricity instead of fossil fuel energy amount.

2 Literature review

There have been different methods of multi criteria decision making and the most known is analytical hierarchy process (AHP). The AHP is developed by Saaty. The principles utilised in AHP to solve problem are to construct hierarchies. The hierarchy allows for the assessment of the contribution individual criterion at lower levels make to criterion at higher levels of the hierarchy. The strength of the AHP approach is based on breaking the complex decision problem in a logical manner into small many small but related sub-problems in the form of levels of a hierarchy. The hierarchical structure of the AHP model permits decision maker (DM) to compare the different prioritisation criteria and alternatives more effectively (Saaty, 1990).

AHP is used to first decompose the decision problem into a hierarchy of easily comprehended sub-problems, each of which can be analysed independently. The elements of the hierarchy can relate to any aspect of the decision problem tangible or intangible, estimated or carefully measured, well or poorly understood.

AHP converts the judgments to numerical values that are processed, evaluated and compared over the entire range of the decision problem. A numerical weight or priority vector is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes AHP from other decision making techniques. At the end of the process, numerical priorities are derived for each of the decision alternatives. It is then a simple matter to pick the best alternative, or to rank them in order of relative preference.

Geographical information system (GIS) is a system that captures, stores, analyses, manages and presents data are linked to locations. GIS takes the number from databases and puts the information in the map as features. The ability to separate information in layers, and then combine it with other layers of information is the reason why GIS hold such great potential as research and decision making tools (Foote and Lynch, 2000; Asifujiang et al., 2012).

The solar mapping for theoretical solar energy potential has been developed based on data available for 30 provinces of Indonesia and presented in the monthly map in GIS technology by the authors (Rumbayan et al., 2012).

The combination of GIS and AHP techniques for analysing land use suitability in Vietnam (Nguyen et al., 2010), site suitability evaluation for ecotourism in Thailand (Bunruamkaew and Murayama, 2011) evaluation of eco-environment quality in China (Ying et al., 2007) have been reported. It was proved that the integration between AHP and GIS can be a powerful tool to develop spatial decision making.

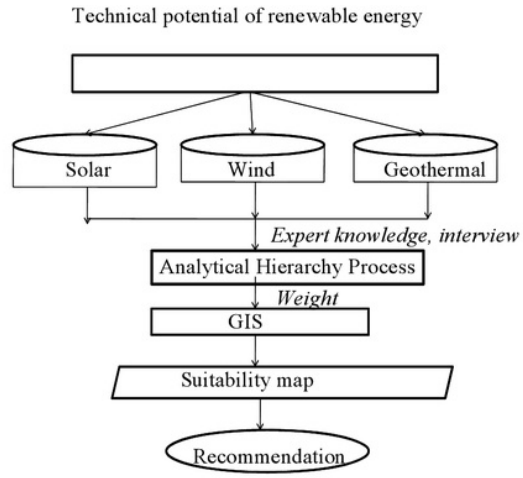
GIS-based multi criteria analysis is widely used as decision and management tool in such fields environment planning and ecology management, urban planning, forestry, hydrology, water resources, agriculture, etc. This current study presents the spatial multi criteria decision making by combining AHP and GIS to prioritise the site for renewable energy development in the wide country such as Indonesia that has many alternatives of resources available.

This current study presents the spatial multi criteria decision making by combining AHP and GIS to prioritise the site for renewable energy development in the wide country such as Indonesia that has many alternatives of renewable energy resources available.

3 Methodology

By using data collected and result of map generated for each resources, i.e., solar, wind and geothermal, this study are conducted for this following objectives. The objectives of this current study are to develop decision making of site prioritisation for renewable energy development in Indonesia and generate resources map by combining AHP and GIS method. Combining AHP with GIS are used as method and presented in Figure 1.

Figure 1 Schematic of the methodology used



The following processes are described in detail as:

1. collect the data
2. develop database for each resources (solar, wind, geothermal)
3. generate thematic resource in GIS environment
4. determine criteria score (x_i) for each resources mapping unit.
5. recommendation for prioritising the site of renewable energy development (based on theoretical potential).

The process can be divided in two phases, firstly, using AHP method then secondly, applying the result of AHP into GIS environment.

The detail procedures by using AHP method are described as follows:

a. Define the objective of decision making (in this study, the recommendation for renewable energy development to be prioritised as site suitability of resources available).

b. Develop the model of AHP-based decision model. The AHP model consists of goal, criteria, and sub criteria in different level. Applying this step to rank or prioritise the decision making for site suitability for renewable energy development, the AHP model is built in this study as shown in Figure 2.

c. Define the pair of criteria (matrix).

   Within each level of the hierarchy, the relative importance between each pair of criteria (or among pairs of sub-criteria relating to an upper single criterion) to overall goal is evaluated. A nine-point scale proposed by Saaty is used for these evaluation based on expert opinion/decision making.

A brainstorming session was conducted among an expert group to assign the values in the matrix as per Saaty's scale that presented in Table 1.

Pair-wise comparison matrix of criteria has shown in Table 2. The matrices of judgments corresponding to the pair-wise comparison of elements at each level of the hierarchy are presented in Table 3.

In this study, all scores can be assembled in a pair wise comparison matrix with 1s on the diagonal (e.g., geothermal to geothermal is 1) and reciprocal scores in the lower left triangle (e.g., if geothermal to solar is 5, and then solar to geothermal is 1/5). Pair-wise comparisons generated for the levels of the hierarchy contain expert opinion regarding the relative importance of criterion. The next step in the AHP requires evaluation of the pair-wise comparison matrices using measurement theory. A standardised eigenvector is extracted from each comparison matrix, allowing us to assign weight to criteria, sub-criteria. These weights allow us to assemble a suitable value for each resources mapping unit.

The weight can be obtained by normalising the vector in each column of the matrix (dividing each entry of the column by the column total) and averaging over the rows of the resulting matrix as shown at last column for criteria (Table 2) and for sub-criteria (Table 3).

The score (x_i) and weight (w_i) for criteria (hierarchy 1) and sub criteria (hierarchy 2) are presented in Table 4.

d Consistency check

For each level in the hierarchy it is necessary to know whether the pair-wise comparison has been consistent in order to accept the results of the weighting. The parameter that is used to check this is called the consistency ratio. A consistency check is performed by adopting the following procedure using equations (1) to (3).

The dominant or principal eigenvector of a matrix is an eigenvector corresponding to the eigen value of largest magnitude (for real numbers, largest absolute value) of that matrix. Calculate the eigen value of $\lambda_{\max}$ as:

$$\lambda_{\max} = \frac{1}{n}\sum_{n=1}^{n}\frac{(AW)_i}{w_i} \quad (1)$$

where A is the matrix, W is the corresponding eigenvector of $\lambda_{\max}$ and w_i ($i = 1, 2, \ldots, n$) is the weight value for ranking.

$$CI = \frac{\lambda\max - n}{n-1} \quad (2)$$

where CI is the consistency index; while $\lambda_{\max}$ is the eigen value and n is the order of the matrix. The bigger CI occurred, the worse consistency the matrix has (Xu, 2000). It is found that the value of CI in this research was pretty good in 0.06. Then, the consistency ratio (CR) was calculated by using equation (3):

$$CR = \frac{CI}{RI} \quad (3)$$

where random index (RI) is the average of the resulting consistency index depending on the order of the matrix. The result below 0.1 shows the consistency of pair wise matrix.

Figure 2 Develop AHP model (see online version for colours)

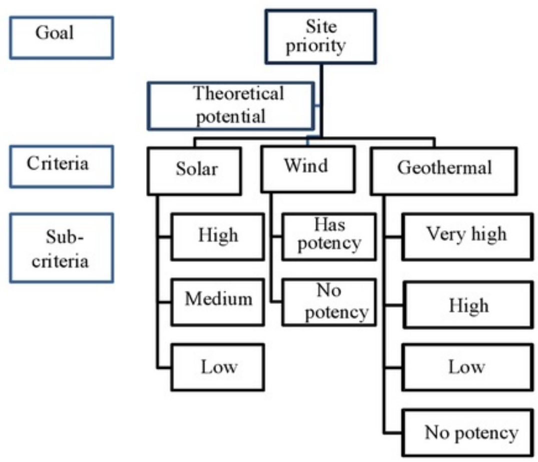


Table 1 Saaty's scale preference in the pair-wise comparison process

Numerical rating	*Verbal judgments of preferences between alternatives i and alternatives j*
1	*i* is equal important to *j*
3	*i* is slightly more important than *j*
5	*i* is strongly more important than *j*
7	*i* is very strongly more important than *j*
9	*i* is extremely more important than *j*
2, 4, 6, 8	Intermediate values

Source: Saaty (1990)

Table 2 Weight of criteria

Criteria	*High*	*Moderate*	*Low*	*Weight*
Geothermal	1	5	9	0.72
Solar	1/5	1	5	0.22
Wind	1/9	1/5	1	0.06

Table 3 Pair-wise comparison of sub-criteria and local weight

Sub-criteria for solar	*High*	*Moderate*	*Low*	*Local weight (w_i)*
High	1	5	9	0.72
Moderate	1/5	1	5	0.22
Low	1/9	1/5	1	0.06

Sub-criteria for geothermal	*Very high*	*High*	*Low*	*No potency*	*Local weight (w_i)*
Very high	1	5	7	9	0.68
High	1/5	1	1/7	7	0.22
Low	1/7	1/5	1	5	0.12
No potency	1/9	1/7	1/5	1	0.04

Sub-criteria for wind	*Has potency*	*No potency*	*Local weight (w_i)*
Has potency	1	9	1
No potency	1/9	1	0

In this study, the consistency check for hierarchy 1 (criteria) is performed as above procedure and presented as follows:

$$\begin{bmatrix} 1 & 5 & 9 \\ 1/5 & 1 & 5 \\ 1/9 & 1/5 & 1 \end{bmatrix} \begin{bmatrix} 0.72 \\ 0.22 \\ 0.06 \end{bmatrix} = \lambda_{\max} \begin{bmatrix} 0.72 \\ 0.22 \\ 0.06 \end{bmatrix}$$

From calculation using equation (1), it is found that eigenvector of AHP model in this research, $\lambda_{\max} = 3.12$. In order to keep the consistency of the judgment matrix, its consistency should be tested by using equations (2) and (3). It is found that consistency ratio equal to 0.04.

The similar way to prove the consistency index of judgment are applied for the pair wise of sub criteria matrix (in Table 3).The result indicates that the pair wise matrix for sub criteria of solar, wind and geothermal are below 10%. Then the local weight for criteria at level 1 are multiplied the local weight for criteria at level 2. Then the total weight is calculated by using equation (4).

$$S = \sum_{i}^{n} w_i x_i \tag{4}$$

where S: suitability index, w_i: weight of criterion i, and x_i: score of criterion i.

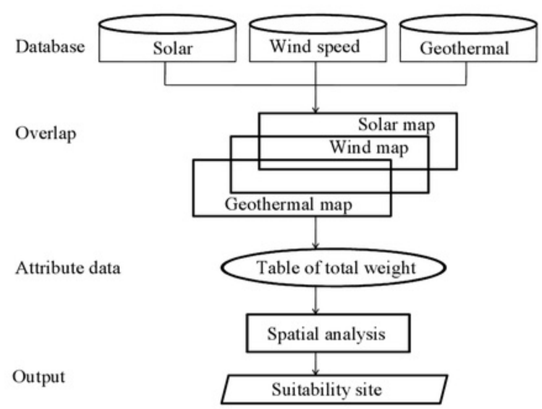
In the second phase, the result of weight or priority of criteria where used as input in GIS in the spatial analysis at GIS environment to overlay the map, as shown in Figure 3.

The entire resource databases which consist of solar, wind, geothermal data are formed in polygon format for 30 provinces as boundary in digital map available. The solar irradiation data for 30 provinces taken from NASA database as monthly average (http://eosweb.larc.nasa.gov); wind speed data also taken from NASA database; the geothermal resources potential data are taken from Pertamina, a energy state of Indonesia.

The previous study about solar irradiation potential, wind energy analysis and geothermal potential analysis were conducted by authors and presented as solar mapping, wind mapping and geothermal mapping for 30 provinces in Indonesia based on data available.

In this study, we overlay all the solar irradiation data, wind velocity data, and geothermal resources potential data which based on geographical data and AHP model, by using GIS technology.

Figure 3 GIS method used in this study



4 Result and discussion

The result of calculation local weight for hierarchy 1 and the total weight for hierarchy 2 (sub-criteria) are presented in Table 4. All pair wise matrix indicates at below 10%, therefore there is no review for pair wise that built based on expert opinion and DM references.

In this study the AHP model was built to identify the weight of criteria for two hierarchies. Then the overall weights were obtained based on AHP method. AHP as a well-known criteria decision making was used to define the weight of potential of resources. The scores and weight of solar, wind, geothermal potential for 30 provinces in Indonesia are presented in Table 5.

GIS enables to generate a theoretical potential resources map based on overlapping solar energy map (Figure 4), wind map (Figure 5) and geothermal potential map (Figure 6).

Table 4 Score and weight in priority site of renewable energy potential analysis

Criteria-hierarchy 1	x_I	*Criteria-hierarchy 2*	w_i	$w_i x_i$
Solar resources	0.22	High	0.72	0.16
		Moderate	0.22	0.05
		Low	0.06	0.01
Wind resources	0.06	Has potency	1	0.06
		No potency	0	0
Geothermal	0.72	Very high	0.68	0.49
		High	0.16	0.12
		Low	0.12	0.09
		No potency	0	0

Table 5 Score and weight of solar, wind, geothermal potential for 30 provinces in Indonesia

Provinces	*Solar weight* $(w_1 * x_1)$	*Wind weight* $(w_2 * x_2)$	*Geothermal weight* $(w_3 * x_3)$	*Total weight*
Aceh	0.01	0.06	0.49	0.56
Medan	0.01	0	0.49	0.50
Padang	0.01	0	0.12	0.13
Riau	0.01	0.06	0	0.07
Jambi	0.01	0.06	0.49	0.56
Palembang	0.01	0	0.12	0.13
Bengkulu	0.01	0.06	0.12	0.19
Lampung	0.01	0.06	0	0.07
Belitung	0.01	0.06	0.12	0.19
Jakarta	0.05	0	0	0.05
Bandung	0.05	0	0.12	0.17
Semarang	0.16	0	0.12	0.28
Yogyakarta	0.01	0.06	0	0.07
Surabaya	0.05	0.06	0.12	0.23
Banten	0.05	0.06	0	0.11
Bali	0.16	0	0.09	0.25
Lombok	0.16	0.06	0.49	0.71
Kupang	0.16	0.06	0.12	0.34
Pontianak	0.05	0	0	0.05
Palangkaraya	0.01	0	0	0.01
Banjarmasin	0.05	0	0	0.05
Samarinda	0.01	0.06	0	0.07
Manado	0.16	0.06	0.49	0.71
Palu	0.16	0.06	0	0.22
Makasar	0.16	0.06	0	0.22
Kendari	0.05	0.06	0	0.11
Gorontalo	0.05	0	0	0.05
Ambon	0.16	0	0.12	0.28
Temate	0.16	0	0	0.13
Jayapura	0.01	0	0	0.01

Figure 4 Solar irradiation map (see online version for colours)

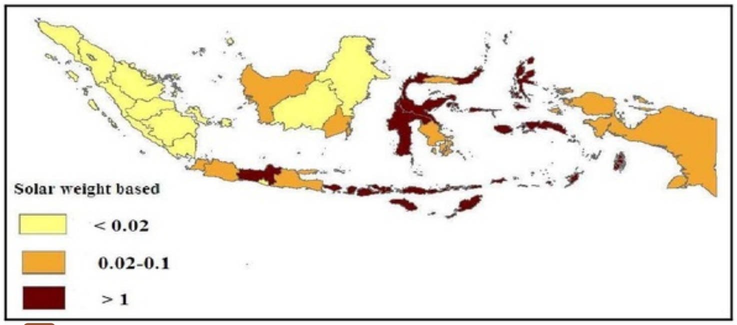


Figure 5 Wind resources map (see online version for colours)

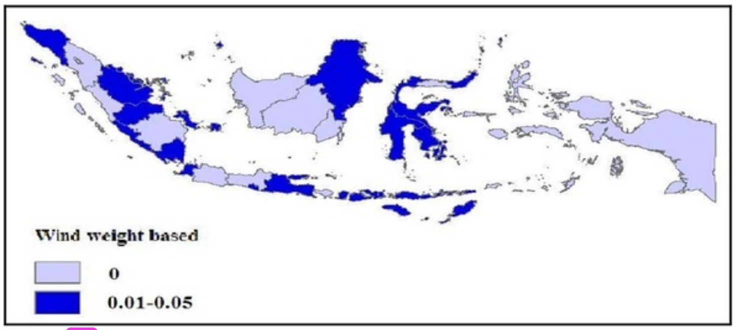


Figure 6 Geothermal resource map (see online version for colours)

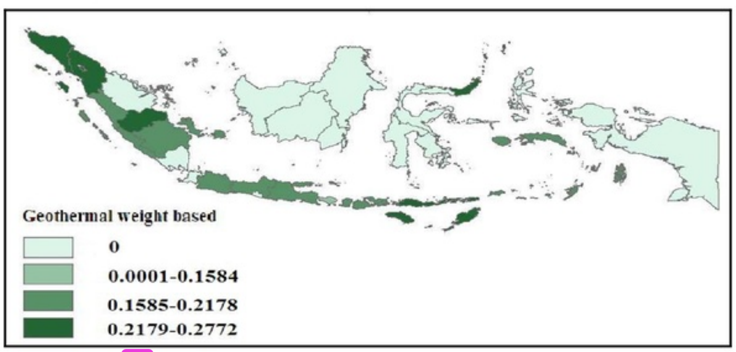
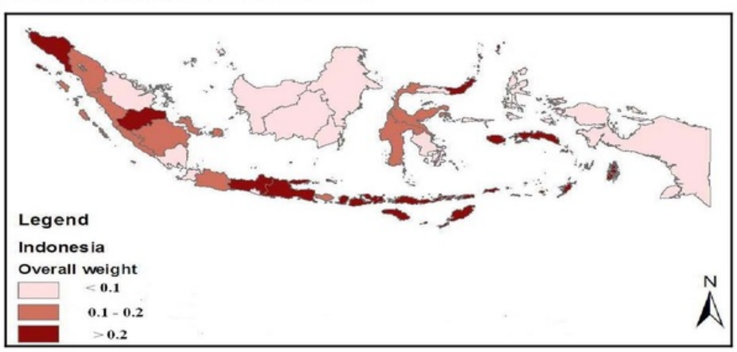


Figure 7 Prioritisation resource map (see online version for colours)



We made the resource map by combining the AHP and GIS to show the suitability site of renewable energy resources for the entire Indonesia as shown in Figure 7.

The GIS technology is used to assist the determination of finding the potential for entire Indonesia (30 provinces). Based on the weight calculation from multi criteria decision making using AHP method, The attribute of rank prioritisation of resources map is classified in three classes, i.e., highly suitable (>0.2), suitable (0.1–0.2) and low suitable (<0.1) and the map is generated in GIS environment.

Basically, the highly suitability site of renewable energy potential are found in province of Aceh, Medan, Jambi, Semarang, Surabaya, Bali, Lombok, Kupang, Manado and Ambon as shown in Table 5. In Figure 7, the colour indicates that the darkest show the high suitability for prioritise of renewable energy development based on theoretical potential criteria.

5 Conclusions

In this study, the resource of renewable energy potential for entire Indonesia has been investigated, with the objective to find suitable sites for prioritising renewable energy development, based on data available regarding theoretical potential of solar, wind and geothermal energy.

The available renewable energy data (solar, wind, and geothermal) have been transformed into GIS-readable data. By using spatial analysis function in GIS technology based on weight calculation by using AHP model, we generated resources map for prioritising the decision for renewable energy development in the suitable site.

The result of this current study found that geothermal is best choice, followed by solar and wind alternatives with weight value of 0.72, 0.22, and 0.06 respectively. Resources map generated identify the highly, moderate and suitability site to priority decision of renewable energy development for Indonesia. The proposed methodology was useful to identify the renewable energy resources site for development priority.

Table 6 Potential of geothermal energy analysis for each location of site priority in Indonesia

No.	*Locations*	*Theoretical potential (MW)*	*Potential energy output (kWh/year)*	*Cost (US$)*	*Potential CO_2 reduction (ton/year)*
1	Aceh	11.85	75,840,000	5,763,840	77,356.8
2	Medan	11.20	71,680,000	5,447,680	73,113.6
3	Jambi	11.50	73,600,000	5,593,600	75,072.0
4	Semarang	4.65	29,760,000	2,261,760	30,355.2
5	Surabaya	2.40	15,360,000	1,167,360	15,667.2
6	Bali	0.75	4,800,000	364,800	4,896.0
7	Lombok	2.50	16,000,000	1,216,000	16,320.0
8	Kupang	16.50	105,600,000	8,025,600	107,712.0
9	Manado	10.25	65,600,000	4,985,600	66,912.0
10	Ambon	7.50	48,000,000	3,648,000	48,960.0

Table 7 Potential of wind energy analysis for each location of site priority in Indonesia

No.	*Locations*	*Theoretical potential (W/m^2)*	*Potential energy output (kWh/year)*	*Cost (US$)*	*Potential CO_2 reduction (ton/year)*
1	Aceh	17.72	10632	882.45	10.84
2	Medan	14.33	8598	713.63	8.76
3	Jambi	33.88	20328	1,687.22	20.73
4	Semarang	2.37	1422	118.02	1.45
5	Surabaya	26.94	16164	1,341.61	16.48
6	Bali	14.38	8628	716.12	8.80
7	Lombok	45.06	27036	2,243.99	27.57
8	Kupang	22.62	13572	1,126.47	13.84
9	Manado	17.04	10224	848.59	10.42
10	Ambon	5.20	3120	258.96	3.18

Table 8 Potential of solar energy analysis for each location of site priority in Indonesia

No.	*Locations*	*Solar irradiation (kWh/m^2)*	*Potential energy output (kWh/year)*	*Cost (US$)*	*Potential CO_2 reduction (ton/year)*
1	Aceh	4.67	1,854,550.4	268,909.81	1,891.64
2	Medan	4.44	1,763,212.8	255,665.86	1,798.48
3	Jambi	4.70	1,866,464.0	270,637.28	1,903.79
4	Semarang	5.42	2,152,390.4	312,096.61	2,195.44
5	Surabaya	5.01	1,989,571.2	288,487.82	2,029.36
6	Bali	5.46	2,168,275.2	314,399.90	2,211.64
7	Lombok	5.42	2,152,390.4	312,096.61	2,195.44
8	Kupang	6.30	2,501,856.0	362,769.12	2,551.89
9	Manado	5.98	2,374,777.6	344,342.75	2,422.27
10	Ambon	5.67	2,251,670.4	326,492.21	2,296.70

The output of this study can be used for decision making to prioritisation area of development in renewable energy for country case. This method of study also suitable/relevant to be adopt for site selection to find priority of renewable energy development as the objective for other country.

For further study, we plan to add other criteria, such as economy and environmental potential to be analysed by using AHP and GIS. Regarding the installing such renewable energies into the candidate power systems, many issues also need to be considered, such as transmission limits (Zeng et al., 2012) and some new simulation and modelling for control of power systems together with renewable energies in connected and stand-alone situations. There are some works on this issues and already published in the *International Journal of Advanced Mechatronic System* as valuable references (Liu et al., 2012; Gharib et al., 2011).

References

Asifujiang, A., Hayashi, Y., Zulati, L. and Nagasaka, K. (2012) 'Off-shore wind power potential evaluation and economy analysis of entire Japan using GIS technology', *International Journal of Advanced Mechatronic Systems*, Vol. 4, No. 2, pp.86–93.

Bunruamkaew, K. and Murayama, Y. (2011) 'Site suitability evaluation for ecotourism using GIS and AHP: a case of Surat Thani Provience, Thailand, International Conference of Spatial Thinking and Geographic Information Sciences', *Procedia Social and Behavioural Sciences*, Vol. 21, pp.269–278.

Foote, K.E. and Lynch, M. (2000) *GIS as an Integrating Technology: Context, Concept and Definitions*, The Geographer's Craft Project, Department of Geography, The University of Colorado, Boulder.

Gharib, M.R., Kamelian, S., Mousavi, S.A. and Dabzadeh, I. (2011) 'Modelling and multivariable robust controller for a power plant', *International Journal of Advanced Mechatronic Systems*, Vol. 3, No. 2, pp.119–128.

Liu, C., Wang, H., Ding, J. and Zhen, C. (2012) 'An overview of modelling and simulation of thermal power plant', *International Journal of Advanced Mechatronic Systems*, Vol. 4, No. 2, pp.76–85.

Nguyen, K., Nguyen, T.T., Nguyen, T.H. and Vu, M.T. (2010) 'Integration of GIS and AHP techniques for analyzing land use suitability in Di Linh District, Upstream Dong Nai Watershed Vietnam', SEARCA Agriculture and Development Discussion Paper.

Rumbayan, M., Abudureyimu, A. and Nagasaka, K. (2012) 'Mapping of solar energy potential in Indonesia using artificial neural network and geographic information system', *Renewable and Sustainable Energy Reviews*, Vol. 16, No. 3, pp.1437–1449.

Saaty, T.L. (1990) *Multi-criteria Decision Making: The Analytic Hierarchy Process*, RWS Publications, Pittsburgh.

Xu, Z. (2000) 'On consistency of the weighted geometric mean complex judgement matrix in AHP', *European Journal of Operational Research*, Vol. 126, No. 3, pp.683–687.

Ying, X., Ming, Z.G., Gui-Qiu, C., Lin, T., Lin, W.K. and You, H.D. (2007) 'Combining AHP with GIS in synthetic evaluation of eco-environment quality: a case study of Hunan Province, China', *Ecological Modeling*, Vol. 209, Nos. 2–4, pp.97–109.

Zeng, A., Qin, X., Wang, Y. and Pan, H. (2012) 'EHV transmission lines fault protection with HHT energy spectrum', *International Journal of Advanced Mechatronic Systems*, Vol. 4, No. 1, pp.18–24.

Development of priority decision for renewable energy potential using analytical hierarchy process and geographical information system method

ORIGINALITY REPORT

23%	19%	20%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	rri.wvu.edu Internet Source	2%
2	ojs.academypublisher.com Internet Source	1%
3	www.northinfo.com Internet Source	1%
4	www.coursehero.com Internet Source	1%
5	www.wseas.us Internet Source	1%
6	Niloofar Nasrollahi, Hossein Kazemi, Behnam Kamkar. "Feasibility of ley-farming system performance in a semi-arid region using spatial analysis", Ecological Indicators, 2017 Publication	1%
7	futurict.lt Internet Source	1%

8	www.waset.org Internet Source	1%
9	kenkyu-web.tuat.ac.jp Internet Source	1%
10	Fan Zhang, Mo Zhou, Qing Lu. "Procurement model for supermarket based on category management", 2010 International Conference on Logistics Systems and Intelligent Management (ICLSIM), 2010 Publication	1%
11	planning.massey.ac.nz Internet Source	1%
12	id.scribd.com Internet Source	1%
13	api.ning.com Internet Source	1%
14	Latinopoulos, Dionysis, and Dimitra Vagiona. "Measuring the sustainability of tourism development in protected areas: an indicator-based approach", International Journal of Innovation and Sustainable Development, 2013. Publication	1%
15	Kumagai, Shunji, Makoto Kasai, Seiji Hashimoto, and Nobuyuki Nagai. "Output	1%

characteristics of multi-axis vibration power generation device for automobiles", International Journal of Advanced Mechatronic Systems, 2013.
Publication

16	Xiong Ying, Guang-Ming Zeng, Gui-Qiu Chen, Lin Tang, Ke-Lin Wang, Dao-You Huang. "Combining AHP with GIS in synthetic evaluation of eco-environment quality—A case study of Hunan Province, China", Ecological Modelling, 2007 Publication	1%
17	www.igutourism.com Internet Source	1%
18	wgbis.ces.iisc.ernet.in Internet Source	1%
19	Gyoo-Bum Kim. "Analytic hierarchy models for regional groundwater monitoring well allocation in Southeast Asian countries and South Korea", Environmental Earth Sciences, 11/2009 Publication	1%
20	Soyoung Park, Seongwoo Jeon, Shinyup Kim, Chuluong Choi. "Prediction and comparison of urban growth by land suitability index mapping using GIS and RS in South Korea", Landscape and Urban Planning, 2011 Publication	<1%

21 www.npaconsult.co.uk
Internet Source

<1%

---

22 Rumbayan, M.. "Mapping of solar energy potential in Indonesia using artificial neural network and geographical information system", Renewable and Sustainable Energy Reviews, 201204
Publication

<1%

---

23 Hiramatsu, Daisuke, Tadashi Tokumasu, Masafumi Fujita, Mikio Kakiuchi, Toru Otaka, Osamu Sato, and Ken Nagasaka. "A Study on Rotor Surface Losses in Small-to-Medium Cylindrical Synchronous Machine", IEEE Transactions on Energy Conversion, 2012.
Publication

<1%

---

24 Dutta, Bapi, and Debashree Guha. "Preference programming approach for solving intuitionistic fuzzy AHP", International Journal of Computational Intelligence Systems, 2015.
Publication

<1%

---

25 www.nature.com
Internet Source

<1%

---

26 Bouamrane, K., D. Hamdadou, Kh. Yachba, and Kh. Guenachi. "Towards a decision support system, application: itinerary road modification for road transport of hazardous materials", International Journal of Decision Sciences Risk

<1%

and Management, 2012.
Publication

27 Meita Rumbayan. "Development of power system infrastructure model for the island communities: A case study in a remote island of Indonesia", 2017 International Conference on Advanced Mechatronic Systems (ICAMechS), 2017
Publication
<1%

28 world-food.net
Internet Source
<1%

29 159.226.115.1
Internet Source
<1%

30 tao.cgu.org.tw
Internet Source
<1%

31 Kelekar, Uma, and Xiang Liu. "Why should 'geography' matter to public health managers?", International Journal of Business Performance Management, 2013.
Publication
<1%

32 Nishigai, Kazuya, Hiroki Nakatsuka, and Kazuyuki Ito. "Control of multi-legged robot using reinforcement learning with body image and application to rubble", International Journal of Advanced Mechatronic Systems, 2013.
Publication
<1%

33	apec2013.or.id Internet Source	<1%
34	kepcorp.com Internet Source	<1%
35	geografie.ubbcluj.ro Internet Source	<1%
36	ce.udel.edu Internet Source	<1%
37	Sutrisno, A, and TJ Lee. "Service reliability assessment using failure mode and effect analysis (FMEA): survey and opportunity roadmap", International Journal of Engineering Science and Technology, 2012. Publication	<1%
38	Hashimoto, Seiji, Nobuyuki Nagai, Shunji Kumagai, and Makoto Kasai. "Effective energy regeneration from multi-mode-based vehicle vibration", International Journal of Advanced Mechatronic Systems, 2013. Publication	<1%
39	eprints.lib.hokudai.ac.jp Internet Source	<1%
40	Bunruamkaew, Khwanruthai, and Yuji Murayam. "Site Suitability Evaluation for Ecotourism Using GIS & AHP: A Case Study of	<1%

Surat Thani Province, Thailand", Procedia - Social and Behavioral Sciences, 2011.
Publication

41 "Ranking the impact of world financial crisis on China", Engineering Technology Engineering Education and Engineering Management, 2015.
Publication
<1%

42 Ashutosh Kumar Mishra, Shikhar Deep, Abhishek Choudhary. "Identification of suitable sites for organic farming using AHP & GIS", The Egyptian Journal of Remote Sensing and Space Science, 2015
Publication
<1%

43 tubdok.tub.tuhh.de
Internet Source
<1%

44 Nakamura, Yukinori, Ryo Fukuda, and Shinji Wakui. "Suppression of flow disturbance to pneumatic active anti-vibration apparatuses by smoothed and shaped signals", International Journal of Advanced Mechatronic Systems, 2013.
Publication
<1%

45 www.ijirset.com
Internet Source
<1%

46 profdoc.um.ac.ir
Internet Source
<1%

47	Mohammad Reza Gharib. "Modelling and multivariable robust controller for a power plant", International Journal of Advanced Mechatronic Systems, 2011 Publication	<1%
48	Baniya, Nabarath(Böhme, Michael H. and La Rosa Perez, Michael). "Land suitability evaluation using GIS for vegetable crops in Kathmandu Valley/Nepal", Landwirtschaftlich-Gärtnerische Fakultät, 2008. Publication	<1%
49	Hassan Z. Al Garni, Anjali Awasthi. "Solar PV power plant site selection using a GIS-AHP based approach with application in Saudi Arabia", Applied Energy, 2017 Publication	<1%

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		

Lampiran 6

LEMBAR
HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW*
KARYA ILMIAH : JURNAL ILMIAH

Judul Karya Ilmiah (artikel : Development of Priority decision for renewable energy potential using Analytical hierarchy process and geographical information system method.

Nama Penulis : Ken Nagasaka, Meita Rumbayan

Jumlah Penulis : 2

Status Pengusul : Penulis ke 2

Identitas Jurnal Ilmiah:
a. Nama Jurnal : International Journal of Advenced Mechatronic System
b. Nomor ISSN : 1756-8420
c. Volume, Nomor, Bulan Tahun : 5,4,2013
d. Penerbit : Inderscience
e. DOI artikel (jika ada) : https://doi.org/10.1504/IJAMECHS.2013.057666
f. Alamat web Jurnal : https://www.inderscienceonline.com/doi/abs/10.1504/IJAMECHS.2013.057666
g. Terindeks di Scimagojr,SCOPUS, SINTA

Kategori Publikasi Jurnal Ilmiah (beri √pada kategori yang tepat)

✓ Jurnal Ilmiah Internasional/Internasional bereputasi*

☐ Jurnal Ilmiah Nasional Terakreditasi

☐ Jurnal Ilmiah Nasional/Nasional terindeks di DOAJ, CABI, COPERNICUS *

Hasil Penilaian *Peer Review* :

Komponen yang dinilai	Nilai Maksimal Jurnal Ilmiah			Nilai Akhir yang Diperoleh
	International/International Bereputasi*	Nasional Terakreditasi	Nasional	
a. Kelengkapan unsur isi artikel (10%)	85			8.5
b. Ruang lingkup dan kedalaman pembahasan (30%)	85			25.5
c. Kecukupan dan kemutakhiran data /informasi dan metodologi (30%)	85			25.5
d. Kelengkapan unsur dan kualitas terbitan/jurnal (30%)	90			27
Total = 100%				
Nilai Pengusul				86.5

Catatan penilaian artikel oleh Reviewer :

terindex scopus.

Manado, November 2018
Reviewer,

Prof. Dr. Ir. Fabian J. Manoppo, M.Agr
NIP. 196210141992031001
Unit kerja : Fakultas Teknik Universitas Sam Ratulangi

HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW* KARYA ILMIAH : JURNAL ILMIAH

Judul Jurnal Ilmiah (Artikel)	:	Development of priority decision for renewable energy potential using analytical hierarchy process and geographical information system method.
Penulis Jurnal Ilmiah	:	Ken Nagasaka, Meita Rumbayan
Identitas Jurnal Ilmiah	:	a. Nama Jurnal : International Journal of Advanced Mechatronic Systems Online ISSN: 1756-8420 https://www.inderscienceonline.com/doi/abs/10.1504/IJAMECHS.2013.057666 b. Volume / Nomor : 5/ 4 c. Edisi (bulan/tahun) : 2013 d. Penerbit : Inderscience e. Jumlah halaman : 9 (hal 270-278)

Kategori Publikasi Jurnal Ilmiah : ☑ Jurnal Ilmiah Internasional
(beri ✓pada kategori yang tepat) ☐ Jurnal Ilmiah Nasional Terakreditasi
☐ Jurnal Ilmiah Nasional Tidak Terakreditasi

Hasil Penilaian *Peer Review* :

Komponen Yang Dinilai	Nilai Maksimal Jurnal Ilmiah			Nilai Akhir Yang Diperoleh
	Internasional ☑	Nasional Terakreditasi ☐	Nasional Tidak Terakreditasi ☐	
a. Kelengkapan unsur isi buku (10%)	88			
b. Ruang lingkup dan kedalaman pembahasan (30%)	90			
c. Kecukupan dan kemutahiran data/informasi dan metodologi (30%)	95			
d. Kelengkapan unsur dan kualitas penerbit (30%)	92			
Total = (100%)				

Malang, November 2017

Reviewer

Prof. Dr. Eng. Ir. Abraham Lomi, MSEE, MIET, SMIEEE
NIP.Y. 1018500108
Unit kerja : Jurusan Teknik Elektro
Institut Teknologi Nasional Malang

Lampiran 6

LEMBAR
HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW*
KARYA ILMIAH : JURNAL ILMIAH

Judul Karya Ilmiah (artikel : Development of Priority decision for renewable energy potential using Analytical hierarchy process and geographical information system method.
Nama Penulis : Ken Nagasaka, Meita Rumbayan
Jumlah Penulis : 2
Status Pengusul : Penulis ke 2
Identitas Jurnal Ilmiah: a. Nama Jurnal : International Journal of Advenced Mechatronic System
b. Nomor ISSN : 1756-8420
c. Volume, Nomor, Bulan Tahun : 5,4,2013
d. Penerbit : Inderscience
e. DOI artikel (jika ada) : https://doi.org/10.1504/IJAMECHS.2013.057666
f. Alamat web Jurnal : https://www.inderscienceonline.com/doi/abs/10.1504/IJAMECHS.2013.057666
g. Terindeks di Scimagojr,SCOPUS, SINTA

Kategori Publikasi Jurnal Ilmiah (beri √pada kategori yang tepat)
✓ Jurnal Ilmiah Internasional/Internasional bereputasi*
☐ Jurnal Ilmiah Nasional Terakreditasi
☐ Jurnal Ilmiah Nasional/Nasional terindeks di DOAJ, CABI, COPERNICUS *

Hasil Penilaian *Peer Review* :

Komponen yang dinilai	Nilai Maksimal Jurnal Ilmiah			Nilai Akhir yang Diperoleh
	International/Internasional Bereputasi* ✓	Nasional Terakreditasi	Nasional	
a. Kelengkapan unsur isi artikel (10%)	90			9
b. Ruang lingkup dan kedalaman pembahasan (30%)	85			25,5
c. Kecukupan dan kemutakhiran data /informasi dan metodologi (30%)	85			25,5
d. Kelengkapan unsur dan kualitas terbitan/jurnal (30%)	85			25,5
Total = 100%				
Nilai Pengusul				85,5

Catatan penilaian artikel oleh Reviewer :
Artikel terindeks.

Manado, 30 November 2017

Reviewer 2

Prof. Dr. Ir. Jefrey I. Kindangen, DEA
NIP. 196506031990031003
Unit kerja : Fakultas Teknik
Universitas Sam Ratulangi

Lampiran 6

LEMBAR (*FORM*)
HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW*
KARYA ILMIAH : JURNAL ILMIAH (*JOURNAL*)

Judul Karya Ilmiah (artikel (Title) : Development of Priority decision for renewable energy potential using Analytical hierarchy process and geographical information system method.

Nama Penulis : Ken Nagasaka, Meita Rumbayan

Jumlah Penulis : 2

Status Pengusul : Penulis ke 2

Identitas Jurnal Ilmiah:
a. Nama Jurnal : International Journal of Advenced Mechatronic System
b. Nomor ISSN : 1756-8420
c. Volume, Nomor, Bulan Tahun : 5,4,2013
d. Penerbit : Inderscience
e. DOI artikel (jika ada) : https://doi.org/10.1504/IJAMECHS.2013.057666
f. Alamat web Jurnal : https://www.inderscienceonline.com/doi/abs/10.1504/IJAMECHS.2013.057666
g. Terindeks di Scimagojr,SCOPUS, SINTA

Kategori Publikasi Jurnal Ilmiah (beri √pada kategori yang tepat)
- ✓ Jurnal Ilmiah Internasional/Internasional bereputasi*
- ☐ Jurnal Ilmiah Nasional Terakreditasi
- ☐ Jurnal Ilmiah Nasional/Nasional terindeks di DOAJ, CABI, COPERNICUS *

Hasil Penilaian *Peer Review* :

Komponen yang dinilai	Nilai Maksimal Jurnal Ilmiah			Nilai Akhir yang Diperoleh
	International/Internnational Bereputasi*	Nasional Terakreditasi	Nasional	
a. Kelengkapan unsur isi artikel (10%)/*Completeness of the content*	90			9
b. Ruang lingkup dan kedalaman pembahasan (30%)/*The Scope and the depth of discussion*	90			27
c. Kecukupan dan kemutakhiran data /informasi dan metodologi (30%)/ *Sufficiency and updated data / information and methodology*	90			27
d. Kelengkapan unsur dan kualitas terbitan/jurnal (30%)/ *Completeness of elements and quality of publications / journal*	90			27
Total = 100%				90
Nilai Pengusul				

Catatan penilaian artikel oleh Reviewer/ Note by Reviewer:

This paper is one of the novel works done in this area.

Tokyo, March 2018

K. Nagasaka 長坂

Prof. Dr. Ken Nagasaka
Department of Electrical and Electronic Engineering