TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol. 13, No. 3, March 2015, pp. 546 ~ 554
DOI: 10.11591/telkomnika.v13i3.7122

Financial Feasibility Study of Waste Cooking Oil Utilization for Biodiesel Production Using ANFIS

Imam Ahmad*[1], Irman Hermadi[2], Yandra Arkeman[3]
[1,2]Departement of Computer Science, Faculty of Mathematics and Natural Sciences,
Bogor Agricultural University, 16680 Bogor, Indonesia, Ph/Fax: +62-251-628448/622961
[3]Departement of Agroindustrial Technology, Faculty of Agricultural Engineering and Technology,
Bogor Agricultural University, 16680 Bogor, Indonesia, Ph/Fax: +62-251-8620224/8621974
*Corresponding author, e-mail: imamahmad666@gmail.com[1], Irmanhermadi@apps.ipb.ac.id[2],
yanda_ipb@yahoo.com[3]

Abstract

Consumption of fuel oil is increasing, but it is not accompanied by supply. Transportation sector is spent the most existing fuel. Therefore, it is crucial to look for alternative type of fuel such as biodiesel to overcome the fuel shortage. The purpose of this study is to investigate the feasibility on how the investment of waste cooking oil as the biodiesel material production. This study consists of two phases. First is calculating feasibility fuzzy model with the input price of biodiesel, waste cooking oil prices and interest rates, and as its output are Net Present Value (NPV), Internal Rate of Return (IRR), Net Benefit Cost Ratio (Net B/C) and Payback Period (PBP). Second is predicting the feasibility of using Adaptive Neuro Fuzzy Inference System (ANFIS). The results of the analysis for each type of membership function (mf) were obtained triangular accuracy77%, accuracy gaussian 53% and trapezoidal accuracy 61%.

Keywords*: ANFIS, biodiesel, feasibility, waste cooking oil*

1. Introduction

Energy is a necessity that cannot be separated from human life, such as fuel oil nowadays consumed increasingly. Agency for the Assessment and Application of Technology in Indonesia revealed that the final energy consumption based on type in 2011 was dominated by the fuel, for example diesel fuel (46%), gasoline (42%), jet fuel (6%), kerosene (3 %) and fuel oil (3%) [1-2]. Thehigh consumption of diesel is triggered by consumption of the motor vehicle. Therefore, the government through the director's decision about Renewable Energy and Energy Conservation Number: 723 K / 10 / DJE / 2013 enforced that 10% blending into diesel fuel and biodiesel quality standards for distribution. Machmud suggested that by mixing 10% (B10) in diesel fuel, it would generate gas emissions (CO and CO_2) in the lowest diesel vehicles [3-4].

Biodiesel is a biofuel, which is made from vegetable oils or animal fats [5]. The process of making biodiesel can be done by esterification and transesterification [6-7]. Biodiesel is a renewable limit fuel and environmentally friendly, and also it produce emission which is relatively cleaner that diesel fuel [8]. In Indonesia, there are 50 types of raw materials which can be used to producebiodiesel [9]. However, there are only six raw material types potentially used for producing biodiesel, namely palm oil, coconut, algae, rubber, and waste cooking oil. Of the six types, cooking oil has the continuous availability. Therefore, waste cooking oils is chosen as the raw material for this research since frying using waste cooking oil is still a great concern [10].

Addition, this research is carried out in one of biodiesel industries in Bogor. According to data from the National Socioeconomic Survey in 2013, the consumption of household cooking oil in Indonesia is 8.9 liters / capita / year. According to the Central Statistics Agency in 2013, the population of Bogor has the densest population in West Java, namely 4,989 million [2]. Furthermore, Environmental Management Agency Bogor recorded in 2011, 16.090 liters of waste cooking oil per year can be processed into biodiesel as 12,050 liters. With the large number of population and the large number of waste cooking oil, it is expected to actively contribute in collecting waste cooking oil. Producing biodiesel from waste cooking oil has two purposes namely incresing food safety of public and enchacing the renewable energy to

Received December 1, 2014; Revised January 31, 2015; Accepted Febrary 14, 2014

produce energy [11]. Thus this study is aimed to determine the feasibility of the waste cooking oil availability collected from the community which can be recycled as biodiesel and gives recommendations about feasibility of biodiesel production economically.

Some research have been done related to feasibility and biodesel production.Amalia et al has been investigated the collecting waste cooking oil in Bogor. In order to see whether or not biodiesel industry is feasibly established, it requires feasibility study to determine whether the industry can provide future benefit [12]. Morover, biodiesel feasibility studies have been carried out by Widodo. He investigated the feasibility of biodiesel industry in producing biodiesel from waste cooking oil using conventional methods [13]. Another study was also done by Martini who investigated fuzzy investment to analyze the financial feasibility of desertification industry based on sugarcane [14]. Furthermore, Shamshirband et alstudied about adaptive neuro fuzzy optimation of wind farm net profit to assess the feasibility of wind power-based electricity industry [15]. Zlender et al have also investigated a feasibility analysis of underground gas storage[16].

However, present research proposes to develop a financial feasibility study model of ANFIS in utilizing waste cooking oil as material for biodiesel production. Financial fasibilty study is importantly investigated as in its process, there are many variables affected feasibility of a investment comparing to other aspects of feasibility. Further, ANFIS, which is a combination of two methods of Neural Network (NN) and fuzzy logic, has advantages of learning (NN), partial truth, and be able to explain the process of reasoning (fuzzy) [17]. Therefore, ANFIS is chosen as it is able to solve uncertainty that can predict an input adaptively.

2. Research Method

2.1. Researh Data

Data is collected from Environmental Management Agency (BPLH) Bogor in 2008-2013and PT. Mekanika Elektrica Egra (MEE). This study is investigated using laptop computer with Processor Intel Pentium(R) CPU P6100 @2.00GHz, random access memory 3 GB. The softwares used are: Windows 7 as operation system, Microsoft Excel for data analysis and Matlab for programming.

2.2. Determining Feasibility Criteria

Feasibility study, basically, is used to determine business feasibility based on investment criteria. Feasibility is an instrument in making decision to finance an investment project based on a technical, economic, and financial [18-19]. Project feasibility assessment should meet some criteria [13], such as, (1) Net Present Value (NPV), (2) Internal Rate of Return (IRR), (3) Net Benefit Cost Ratio (Net B/C) and (4) Payback Period (PBP) (see Table 1). The criteria are chosen as they are part of investment criteria which the analysis is based on cash flow.

Table1. Fuzzy Criteria in Feasibility Assessment

Criteria	Not Feasible	Fairly Feasible	Feasible	Strongly Feasible
NPV[1]	< 0	0 < NPV ≤10% * Inv	8% * Inv < NPV ≤17% * Inv	NPV > 15% * Inv
IRR[2]	< r	r ≤ IRR ≤6% + r	4% + r < IRR ≤ 15% + r	IRR ≥ r + 12%
B/C R[3]	< 1	1 < B/C ≤1,3	1,25 < B/C ≤1,75	B/C > 1,6
PBP[4]	>10	10 > PBP ≥ 5	5,5 < PBP ≤ 1,25	PBP ≤ 1,5

Source: Martini (2010)

2.3. Pre-process

It needs to identify and calculate the feasibility study from economic aspects before investing, such as, identifying the assumptions, investment cost, operational cost comprising fixed and variable costs. The first process is to create fuzzification value in input variables for biodiesel price, waste cooking oil price and interest rate by using *Triangular Fuzzy Number* (TFN) [20]. Feasibility of this study is assessed based on four criteria as follows.

2.3.1. NPV Fuzzy

According to Chiu dan Park [21], when cash flow is influenced by interest rates by using the fuzzy investment, fuzzy NPV can be calculated if there are fuzzy parameters. The equation (1) is:

$$PV_i = \sum_{t=0}^{n} \frac{Ft}{\prod_{x=0}^{t}(1+r_x)^t}$$

Where:
Ft = Cash Flow
i = Fuzzy representation (TFN)
PVi = (ai, b_i, c_i)
Each PV (TFN) has three values, they are:
PV$_1$ = (a_1, b_1, c_1)
PV$_2$ = (a_2, b_2, c_2)
PV$_3$ = (a_3, b_3, c_3)

$$PV_i = \begin{bmatrix} \sum_{t=0}^{ni} \left(\frac{max\{f_{t0},0\}}{\coprod_{x=0}^{t}(1+r_{x2})} + \frac{min\{f_{t0},0\}}{\prod_{x=0}^{t}(1+r_{x0})} \right) \\ \sum_{t=0}^{ni} \frac{f_{t1}}{\prod_{x=0}^{t}(1+r_{x1})}, \\ \sum_{t=0}^{ni} \left(\frac{max\{f_{t2},0\}}{\coprod_{x=0}^{t}(1+r_{x0})} + \frac{min\{f_{t2},0\}}{\prod_{x=0}^{t}(1+r_{x2})} \right) \end{bmatrix}$$

2.3.2. Benefit Cost Ratio (B/C Ratio) Fuzzy

B/C Ratio is value comparing between project benefit and cost of a project spent. This study adopted Kahraman [22] method used Equation (3) as follows.

$$B/C = \left(\frac{\sum_{t=0}^{n} B_t^l (1+r^r)^{-t}}{\sum_{t=0}^{n} C_t^r (1+r^l)^{-t}}, \frac{\sum_{t=0}^{n} B_t^r (1+r^l)^{-t}}{\sum_{t=0}^{n} C_t^l (1+r^r)^{-t}} \right) < \quad (3)$$

2.3.3. Internal Rate of Return (IRR) Fuzzy

Similar to NPV value, IRR is also uncertain. IRR is the return of investment based on interest rate per year. This study is used Equation (4) as follows.

$$\sum_{t=0}^{n} \frac{Ft}{(1+IRR)^t} - Io = 0 \quad (4)$$

2.3.4. Payback Period (PBP) Fuzzy

PBP refers to the estimation in what year the investment value will return. I is the value of investment, Ab is net benefit obtained. This study is used Equation (5) as follows.

$$\text{PBP} = \frac{\text{I}}{\text{Ab}} \quad (5)$$

2.4. Rule Base IF-THEN

Value input in this study is fuzzy variables where for the biodiesel price, waste cooking price and interest rates assumed by the low, moderate and high criteria. These three input variables and three criteria are obtained 3^3 = 27 as a feasibility rule base.

2.5. Development of ANFIS

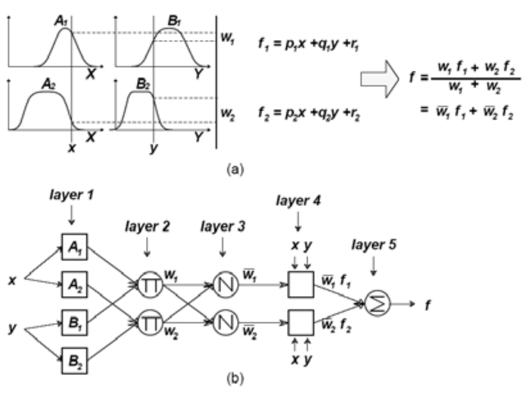


Figure 1. (a) Sugeno Model Orde 1; (b) Architecture ANFIS (Jang 1993)

ANFIS (Adaptive Neuro Fuzzy Inference System) is a combination of two methods namely neural network and fuzzy inference system (FIS). FIS used in this study is Sugeno Model Order 1. The combination of both results adaptive models to the data input [15]. ANFIS architecture showed in Figure 1.

ANFIS architecture consists of five layer [23], as follows:

1. Each node i in the first layer is adaptive towards parameters of an activation function. The output of each node in the form of membership degrees given by the input membership functions. This study is used a triangular membership function (Figure 2) with the Equation (6) is:

$$O_{1,i} = x(\mu(x)) = \begin{cases} 0 & ; x \leq a \ or \ x \ \geq c \\ \frac{(x-a)}{(b-a)} & ; a < x \leq b \\ \frac{(c-x)}{(c-b)} & ; b < x < c \end{cases} \quad (6)$$

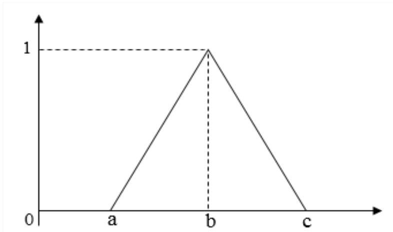


Figure 2. Triangular Fuzzy Number (TFN)

Where {a, b, c} are the parameters, b = 1 as an absolute value. If the value of these parameters are changed, then the shape of the curve will also change. The parameters in this layer is usually called the premise parameters.

2. Each node in the second layer is fixed nodes which its outputs resulted from entire input signal. In general, AND operator is used. Each node represents α predicate of the i-th rule (Equation 7).

$$O_{2,i} = \text{wi} = \mu \ Ai \ (x) \ \mu Bi \ (y) \quad (7)$$

3. Each node in the third layer is fixed nodes which are the result of the ratio calculation of α predicate (wi), from the rules of i-th on the overall amount of α predicate. Equation (8) as follow:

$$O_{3,i} = \ w_i = \frac{w_i}{w_i + w_2} \quad (8)$$

4. Each node in the fourth layer is adaptive node to an output. With *wi* is the normalized firing strength on the third layer and {p_i, q_i, r_i} are the parameters on the node. The parameters in this layer arecalled consequent parameters Equation (9).

$$O_{4,i} = wifi = \ wi \ (pix \ + \ qiy \ + \ ri) \quad (9)$$

5. Every neuron in the fifth layer is a fixed node that is the sum of all inputs, as Equation (10) below.

$$O_{5,i} = \ \sum w_i f_i \frac{\sum_i w_i f_i}{\sum_i w_i} \quad (10)$$

ANFIS development done using Matlab, the first step input value obtained from the 27 conditions of feasibility. Total data obtained from the conditions of feasibility are 810 pairs of data. However, validation of the total data was obtained 708 valid data. The result of this validation is input into ANFIS with 85% training data and 15% testing data.

2.6. Analysis and Evaluation

Analysis was carried out by comparing the results from both conventional fuzzy feasibility model and ANFIS model prediction developed. The latter model results small error, accuracy, and consistency. Evaluation done is changing mf triangular, gaussian and trapezoidal. Testing was carried out with a pair of input data and those three membership functions.

3. Results and Discussion

3.1. Data of Research

Data were obtained from PT. MEE and BPLH Bogor which can be seen in Table 2. The fuzzy variable values are biodiesel price, waste cooking oil price, and interest rate. All three are represented in TFN as low, moderate and high condition (see Figure 3).

Table 2. Biodiesel Price and Waste Cooking Oil in the Last Six Years

No	Year	Waste Cooking Oil (Liter/year)	Waste Cooking Oil Price (Rp/Liter)	Biodiesel Production (Liter/year)	Biodiesel Price (Rp/Liter)
1	2008	3,120	2,500	2,496	6,500
2	2009	5,984	2,500	4,787	6,500
3	2010	10,950	3,000	8,760	6,500
4	2011	16,090	3,000	12,050	6,500
5	2012	16,600	3,000	13,280	9,000
6	2013	91,565	3,000	68,961	9,000

Source: BPLH 2012

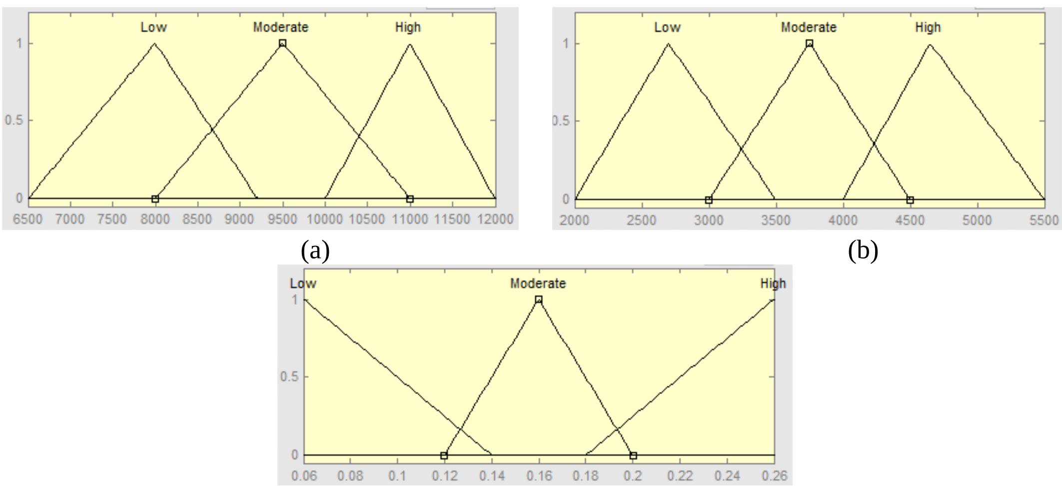


Figure 3. Representation of TFN (a) biodiesel price, (b) WCO price, and (c) interest rate

Data needed for the feasibility of fuzzy model was originally collected in the form of a percentage of biodiesel production in the first, second, third until the tenth year. Furthermore, the other assumptions are: the percentage of biodiesel sales, investment costs (Rp.667.128.000), fixed costs (Rp.96.000.000) and variable costs (Rp.250.800.000). The supporting assumptions are the cost of the investment which is 100% own capital and biodiesel production as much as 3 times a day, 150 liters per production in 28 working day in a month.

3.2 Rule Base *IF-THEN*

Rule base used in this study were obtained from the conditions of 27 feasibility data (Table 3) in which the conditions are when prices and interest rate fluctuations changing to be low, moderate and high. The process of taking crisp value of the four indicators; NPV fuzzy, IRR fuzzy, B/CR fuzzy and PBP fuzzy is by giving weight to each indicator. Determination of crisp values in this fuzzy feasibility study uses Centroid method by giving weight for each indicator and when it is added together yielding value as 1 [24]. Each indicator has a weight to PBP = 0,25, NPV = 0,25, IRR = 0,25 and B/CR = 0,25. Furthermore, the feasibility criteria are divided into fournamely not feasible (0), fairly feasible (1), feasible (2) and strongly feasible (3). The determination of 27 feasibility conditions shown in part in Table 3.

Table 3. Determination of Feasibility Conditions

No	Biodisel Price	WCO Price	interest rate	Feasibility				Agregation	
1	Low	High	Low	PBP	-68.94	Not Feasible	0	Not Feasible	0
				NPV	-759,573,220	Not Feasible	0		
				IRR	-0.39	Not Feasible	0		
				B/C R	0.76	Not Feasible	0		
2	Low	Moderate	Low	PBP	9.65	Fairly Feasible	1	Fairly Feasible	1.25
				NPV	274,129,279	Strongly Feasible	3		
				IRR	0.08	Not Feasible	0		
				B/C R	1.04	Fairly Feasible	1		
3	Low	Low	High	PBP	3.68	Feasible	2	Feasible	2.00
				NPV	539,213,403	Strongly Feasible	3		
				IRR	0.20	Feasible	2		
				B/C R	1.18	Fairly Feasible	1		
4	High	Low	Low	PBP	1,51	Feasible	2	Strongly Feasible	2.75
				NPV	4,162,433,248	Strongly Feasible	3		
				IRR	1.04	Strongly Feasible	3		
				B/C R	2.08	Strongly Feasible	3		

3.3. Development of ANFIS Model

In development of ANFIS, there are training data and testing data. Total data obtained from the fuzzy feasibility study is 810 data, but not all of the data included in the ANFIS model. This is because there are some data with large error exceeding 0.5; therefore, it is obtained 708 valid data after validation shown in Table 4. The data are trained by as much as 100 epochs and error tolerance 0.01.

Table 4. The Total Data Before and After Validation

No	Feasibility	Data	
		Invalid	Valid
1	Not Feasible	120	108
2	Fairly Feasible	150	145
3	Feasible	420	390
4	Strongly Feasible	120	65
Total data		810	708

3.4. Analysis and Evaluation

The sensitivity analysis is performed by comparing the conventional model and ANFIS developed. Widodo's study, using conventional model, showed thatbiodiesel prices decrease 24%, resulting fairly feasible criteria with crisp value as (1.5) and the price of waste cooking increased by 57% with fairly feasible criteria (1.5). ANFIS model is developed with the same input value for 57% increasing biodiesel price resulting fairly feasible criteria with crisp value as 0.7 and 24% decreasing waste cooking oil price resulting fairly feasible criteria (0.9). It means that ANFIS model developed have been successfully approached the feasibility of conventional model. Reduction exceeded the value of the investment criteria is not feasible.

In this stage, evaluation is carried out by testing using pairs of input data. Moreover, testing of data is done by using testing data from training result. Testing is also done by 100 epoch and 0.01 error balance and the results successfully approach target value. The result of testing is showed in Table 5.

Table 5. Sampel of Data Testing in ANFIS

No	Input			Target	Output	
	Biodiesel price (Rp)	Waste cooking oil price (Rp)	Interest rate (%)		Model	Error
1	9000	3000	12	2	2.2379	-0.2379
2	10500	3000	12	3	3.3544	-0.3544
3	11000	5300	26	1	0.6728	0.3272
4	9000	5300	12	0	0.3804	-0.3804

In addition, testing of feasibility ANFIS model using various types of membership function such as triangular, and trapezoidal gaussian. As showed in Figure 4(a), (b) and (c), each type of membership function (mf)of ANFIS target model have successfully approached the target value of pair input data. The results of the accuracy of each mf differ due to the output model is very influential on the mf value. The better mf value the better model resulted. In brief, the result of testing on the pairs data in the input ANFIS approaches target value.

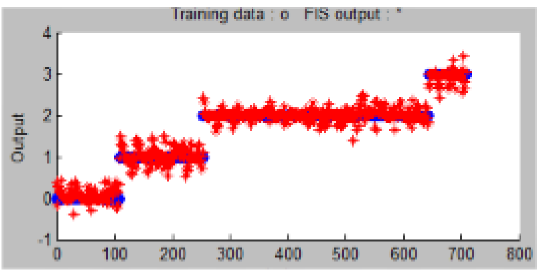
Statistics calculation tool used to test the accuracy of ANFIS are the accuracy testing on the input data and RMSE (Root Mean Square Error). The equations are:

$$Accuracy = \frac{correct\ data}{total\ data}\ x\ 100\%$$

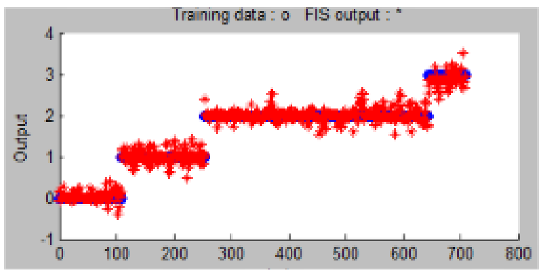
Where correct data = ANFIS training data , total data = number of input data. Therefore, data accuracy obtained for triangular are 77 % , Gaussian 53 % and trapezoidal 61 %.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{Np}(y_{oi}-y_{pi})^2}{Np}}$$

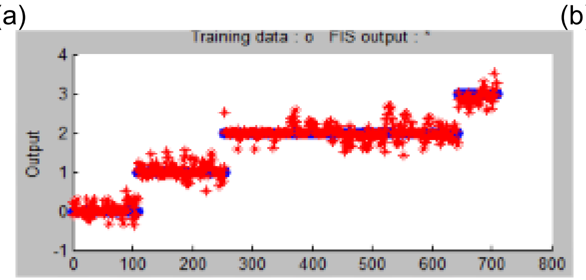
Where yoi = target training data from period i until n , ypi = target model of ANFIS data from period i until n. Thus, by these equations, RMSE values are obtained for triangular 0.02460, gaussian 0.02005 and trapezoidal 0.02862. The results of ANFIS model have approached the training error tolerance value determined previously by 0.01 with 100 epochs.



(a)



(b)



(c)

Figure 4. Plot of Training Result Datamf (a) Triangular, (b) Gaussian, and (c) Trapezoid

4. Conclusion

This study has reached some conclusions. The result of feasibility study analysis using Anfis showed that the biodiesel industry assumed for about 10 year old project is feasible to be developed on sensitivity level of increasing price 57% (crips 0,7) and decreasing price 24% (crips 0,9) which sucsessfully approach the target 1. Fuzzy is able to predict possibility risk in investment as feasibility value based on reasoning. Model feasibility study Anfis has been developed by pair data input; therefore, the results of accuracy MF triangular are 77%, MF gaussian 53%, and MF trapezoid 61%.

In addition, suggestion for further research is that it is better to calculate feasibility study for more than 10 years to obtain more data. Therefore, it will increase the accuracy. Moreover, future research, about fuzzy representation low, moderate, and high, can be used Genetic Algoritm to obtain optimal parameter value.

Acknowledgements

I would like to express my special thanks of gratitude supervisor commission who gave me golden guidance until I am able to complete this research, as well as the Directorate General of Education in Higher Education (DIKTI) and Computational Intelligence Group for Advanced Research and Technology Innovations of Supercomputing (CIGARIS), i.e SMART-TIN© Projectwhich respectively have contributed funds to study and suggestions for me.

References

[1] Badan Pusat Statistik. *Statistik Daerah Kabupaten Bogor Tahun 2013*. No.3201.11.02. 2013.
[2] Sastratenaya A.S, Sudi, A. *Nuclear energy development in Indonesia*. In: Proceedings of the IAEA TC Workshop Long Range Planning, Vienna, 2010.
[3] Machmud S. Pengaruh perbandingan solar-biodiesel (minyak jelantah) terhadap emisi gas buang pada motor diesel. *JANATEKNIKA*. 2009; 11(2):107-116.
[4] Kamahara H, Hasanudin U, Widiyanto A. Tachibana R, Atsuta Y, Goto N, Daimon H, and Fujie K. Improvement potential for net energy balance of biodiesel derived from palm oil: A case study from Indonesian practice. *Biomass and Bioenergy.* 2010; 34(2010):1818-1824. doi:10.1016/j.biombioe.2010.07.014.
[5] Aziz I, Nurbaiti A, Ulum B. Pembuatan produk biodiesel dari Minyak Goreng Bekas dengan Cara Esterifikasi dan Transesterifikasi. *Jurnal Valensi.* 2011; 2(3):443-448.
[6] Zhang Y, Dude MA, McLean DD, Kates M. Biodiesel production from waste cooking oil: 2. Economic assessment and sensitivity analysis. 2003; 90(2003):229-240 DOI:10.1016/S0960-8524(03)00150-0.
[7] Fujita H, Okuhara K, Nakano K, Tsubaki H. *Environmental Analisys of Waste Cooking Oil Recycling and Complete Use Practice in Bogor, Indonesia*. *International Conference on Technology, Informatics, Management, Engineering & Environment*. Bandung. 2013; 28-31.
[8] Kuncahyo P, Fathallah AZM, Semin. Analisa prediksi potensi bahan baku biodiesel sebagai suplemen bahan bakar motor diesel di Indonesia. *Jurnal Teknik Pomits.* 2013; 2(1): 62-66.
[9] Aminah S, Isworo TJ. Praktek Penggorengan Dan Mutu Minyak Goreng Sisa Pada Rumah Tangga RT V/III Kedungmundu Tembalang Semarang. *Prosiding seminar nasional UNIMUS 2010*. 2010; ISBN: 978.979.704.883.9
[10] Zhang H, Ozturk AU, Wang Q, Zhao Z. Biodiesel produced by waste cooking oil Review of recycling modes in China, the US and Japan. 2014; 38(2014): 677-685.
[11] Amalia F, Retnaningsih, Johan IR. 2010. Perilaku penggunaan minyak goreng serta pengaruhnya terhadap keikutsertaan program pengumpulan minyak jelantah di kota Bogor. *Jurnal Ilmu Keluarga Dan Konsumen* 3(2):184-189.
[12] Widodo PSP. Analisis kelayakan usaha pengolahan minyak jelantah menjadi biodiesel. Bogor (ID). Institut Pertanian Bogor. 2011.
[13] Martini S, Model investasi fuzzy untuk analisis kelayakan finansial usaha diversifikasi industri berbasis tebu. *Jurnal Sosial Ekonomi Pertanian dan Agribisnis*. 2010; 10(2):134-140.
[14] Shamshirband S, Petkovic D, Cojbasic Z, Nikolic V, Anuar NB, Shuib NLM, Kiah MLM, Akib S. Adaptive neuro-fuzzy optimization of wind farm project net profit. *Energy Conversion and Management.* 2014; 80(2014):229-237. DOI: 10.1016/j.enconman.2014.01.03.
[15] Loan, Viorica. Financing Invesment Project the Relationship Between Feasibility Study and Business Plan. Annals of Dunarea de Jos Universiti. Fascicle i: *Economic and Applies Informatics*. 2010; 1(2010): 125-130.
[16] Sheen NJ. *Fuzzy Economic Decision modelsfor Information Security Investment. Proceedings of the 9th WSEAS Int.* Conference on Instrumentation, Measurement, Circuits and Systems. Taiwan. 2007; ISBN: 978-960-474-174-8. 141-147.

[17] Nasution H, Jalamaluddin H, Syeriff MJ. 2011. Energy Analysis for Air Conditioning System Using Fuzzy Logic Controller. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2011; 9(1): 139-150.
[18] Chiu CY and Park CS. Fuzzy cash flow analysis using present worth criterion. *The engeneering economist.* 1994; 39(2): 113-137.
[19] Kahrahman C, Tolga E, Ulukan Z. Justification of manufacturing technologies using fuzzy benefit/cost ratio analysis. *International J. Production Economics*. 2000; 66. 45-52.
[20] Jang JSR. ANFIS: Adaptive Network Based Fuzzy Inference System. *IEEE Transaction on System, Man, and Cybernetics*. 1993; 23(3): 665-685.
[21] Kaufmann A, Gupta MM. *Introduction to fuzzy arithmetic*: theory and applications. New York: Van Nostrand Reinhold. 1988;