

Identifying waste cooking oil chains to become an energy resource: study case in Yogyakarta

Amalia Yuli Astuti^{1,a}, Utaminingsih Linarti^{1,b} and Mohamad Tri Angga
Yulistiyanto^{1,c}

¹Department of Industrial Engineering, Faculty of Industrial Engineering, University of Ahmad Dahlan, Yogyakarta, Indonesia

^aamalia.yuliasuti@ie.uad.ac.id, ^butaminingsih.linarti@ie.uad.ac.id, ^cmohamadangga@gmail.com

Keywords: waste cooking oil, supply chain, benefit cost ratio, chain management, waste bank

Abstract. Waste Cooking Oil (WCO) is classified as municipal waste that potentially could pollute the environment. The form of the chains for waste cooking oil management has never been identified so the benefits are still unknown to the community. Up till now, waste cooking oil is always dumped into drains or sold to third-party collectors for converting it to be residual bulk oil. The risk of dumping waste cooking oil into drains can make the water source pollution. If it is reprocessed for human consumption, it can cause diseases. The added value of waste cooking oil is when converted to energy resource. In Yogyakarta, the chains for waste cooking oil management involved waste banks and Bumdes X that came from Bantul regency. Benefit Cost Ratio (BCR) method was used to determine the added value of the waste cooking oil chains so that it can be used as an energy resource. The BCR for existed WCO chains was less than one because the research didn't consideration illegal chains.

Introduction

Waste Cooking Oil (WCO) is one kind of municipal wastes that produced from food processing activities in households, restaurants, and catering businesses. WCO is classified as municipal wastes by European Commission Decision 2000/532/EC in European Waste Catalogue with code number 20 01 25 [1]. In Indonesia, WCO is also treated as municipal wastes but the management for it is very poor. The awareness of waste cooking oil is low in the public community. WCO is usually disposed through sewage drains. These disposal activities will make water source become polluted.

The other concern about disposal system for WCO is food safety when community sold their WCO to third-party collectors. The third-party collectors sold the reprocessed WCO as residual bulk oil without any brands and proper packaging. These residual bulk oil will be back to the food chain but the safety for food that fried with this oil could not be secured. In 2014, Taiwan got a headline for food safety scandal involving the usage of residual bulk oil [2]. WCO will become threats if it is not treated well.

In Indonesia, the concern for WCO is still poor although government has already legalized regulation for municipal waste management [3]. The ministry of environment also has legalized regulation to apply 3R (Reduce, Reuse, and Recycle) activities through waste banks [4]. In Yogyakarta, the local government has legalized the regulation for waste disposal management but only for organic and inorganic waste [5]. The threat from WCO has not yet reached the government and local government. Bogor Environmental Management Agency has already taken a step to recycle WCO became biodiesel [6], collaborated with local schools, restaurants, food stalls, a recycling company, and public transportation company [7].

The chain of WCO has not yet known to public, the community didn't know where their disposal WCO come through. It is important to identify the chain of WCO in Yogyakarta, especially when Yogyakarta Environmental Management Agency has encouraged waste banks to manage municipal waste. Therefore, the purpose of this research are to identify the WCO chains in Yogyakarta and to examine the benefit of the chains with Benefit-Cost Ratio (BCR) method.

Literature Review

Waste Cooking Oil (WCO). The waste definition is different through aspects. Deba et al [8] explained that a waste became waste when it lost the primary function, but someone's waste will become someone else's raw material. Cooking oil becomes a primary ingredient for food processing that is easy to use. WCO is a liquid waste that come from food processing with cooking oil by frying. According to Tsai [9], some dangerous substances such as free fatty acid in WCO could cause corrosion of metal and concrete elements, this substance also make bad odor. WCO could be harmful to human if reprocessed in food chain again. In the other side, WCO also have negative impact to environment. The issue of pollution is eutrophication process that happen in river when WCO become obstacles to sunlight as thin layer oil [10].

The collectable potential for WCO in Indonesia from gastronomy sector was 646.800 million tons in 2013, exclude from household and others potential source [11]. The potential source from selected countries is in Figure 1. The total WCO from this figure was 4.551.900 million tons [11]. Furthermore, WCO potential in Indonesia is more than the recorded data.

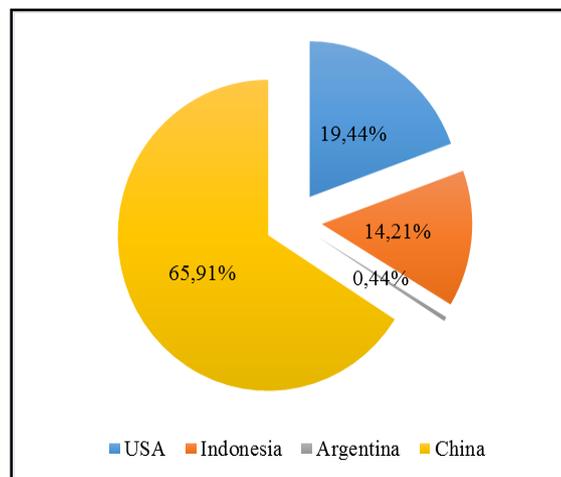


Fig. 1. The potential for WCO from gastronomy sector in selected countries [11]

Waste Cooking Oil Chains and Recycling Modes. WCO became noticeable in recent years as municipal waste that should be managed carefully. The discussion of WCO potential become biodiesel is arising [12,13,14]. USA, European Union, Japan, China, Brazil, and Taiwan have already taken steps to recycle WCO became biodiesel [9,11,15,16,17]. The chains of WCO become biodiesel were transported via recycling modes. Zhang et al [15] explained that WCO recycling modes to biodiesel can be categorized as the biodiesel enterprise take-back (BET) and the third party take-back (TPT). Furthermore, the stakeholders for WCO chains in China are government, biodiesel manufacturers, third party providers, illegal manufacturers, and restaurant [15]. Vinyes et al [18] classified three systems to collect WCO, namely, door-to-door (DTD) systems, schools (SCH) system, Urban Collection Centers (UCC) system. Although, there were many modes or systems to WCO chains converted to biodiesel but the BET and TPT were the modes that implemented in USA, Japan, and China [15]. In other side, the SCH system and UCC system were adopted in Bogor, Indonesia [6]. Furthermore, each modes and systems have benefit and essential for each cases.

In China, Japan, and USA cases for WCO collection through recycling modes were already engaged government participation [15]. For WCO chains mechanism, stakeholders need subsidy and recycle fee regulation. The chains of WCO in USA and Japan didn't involve the illegal manufacturers because governments have strict penalty and controllable mechanism [15]. Without that, the chains would be back to food chain or polluted the environment. But in Indonesia, there is no special regulation or subsidy for WCO chains mechanism.

Research Method

This research purpose was to explore the WCO chains in the Yogyakarta City, Special Region of Yogyakarta, Indonesia. The information about the chains were still unidentified. The only information was obtained when interviewed the waste banks managers at Brontokusuman. Therefore, snowball sampling method was adopted to obtain more information about WCO chains. The boundary of research was the Yogyakarta city through waste banks. The methods for this research to gather information were interview and observation. After the chains were obtained, the research applied BCR method to determine the added value of WCO.

Snowball Sampling. Snowball sampling is sampling method that commonly used in social studies. This sampling technique offers benefit to research that search access to difficult or hidden population [19]. Atkinson and Flint [19] explained that the advantages for this method are:

1. Snowball sampling has enabled to access hidden populations.
2. The method has been found to be economical, efficient, and effective in various studies.
3. Snowball sampling can produce in-depth result within relatively quickly time.

In other hand, because this method is used to reach hidden population so trusts are very critical in process. Respondents are not the source information but also as research assistants [19].

Benefit-Cost Ratio (BCR) Analysis. BCR analysis is one of method to measure of economic attractiveness which to know the return of investment [20,21]. The concept of using BCR is related to benefit and disbenefit. BCR is the method that usually use to measure the feasibility of public projects. When BCR is used to measure public projects so the benefits are the consequences to community [20]. The result of BCR can be positive or negative according to the cases or projects. But the positive result is the feasibility measure for BCR when $B/C \geq 1$ [20,21]. The equation of the BCR, which is [21]:

$$\frac{B}{C} (BCR) = \frac{PW \text{ of benefits}}{PW \text{ of costs}} = \frac{EUAB}{EUAC} \geq 1 \quad (1)$$

Where, B = benefit,

C = cost,

PW = present worth,

EUAB = equivalent uniform annual benefit,

EUAC = equivalent uniform annual cost.

Result and Finding

The WCO Chains in Yogyakarta City. The data were obtained through waste banks insider in Yogyakarta city. Those managers of waste banks became this research first respondent. This research found that Bumijo waste bank is the biggest collector in Yogyakarta city. Bumijo waste bank collects WCO from other waste banks, that are Suronatan, Kauman, Karangajen, Kotagede, and Suryadiningratan waste banks. This five waste banks collect WCO from households in their area. Then, Bumijo waste bank sells it to Bumdes X in Bantul regency. Bumdes X is the only one in Bantul that reprocesses WCO by filtering it. After reprocessing WCO, Bumdes X sells it to a manufacturer in Klaten regency that owned by multi-national company. This manufacturer is using the WCO from Bumdes X as energy source to heater machine. The data were obtained within February until August in 2018. The WCO chains can be found in Figure 2.

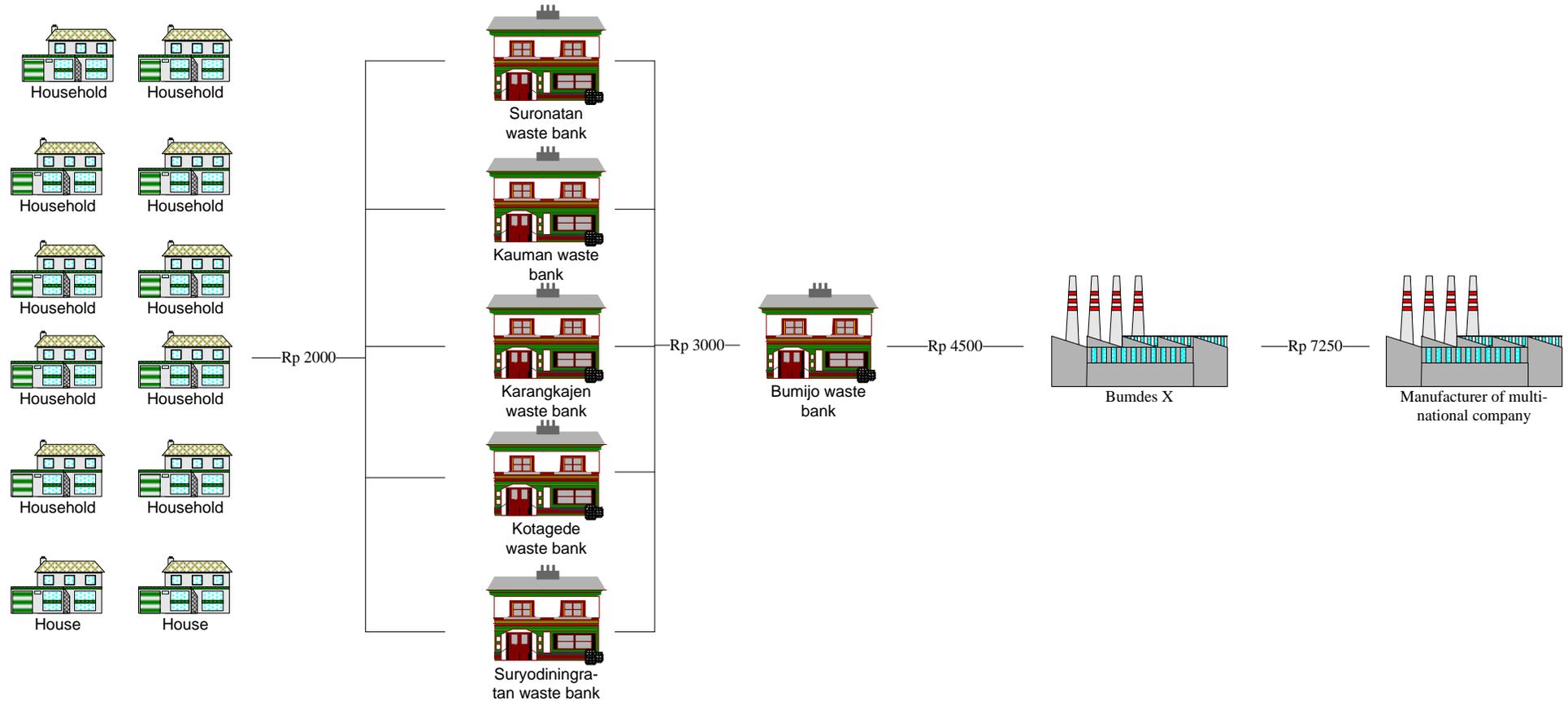


Fig. 2. The WCO chains in Yogyakarta

This existed WCO chains in Yogyakarta city are through waste banks because the local government encouraged the program of 3R as Yogyakarta becomes tourists' destination city. After interviewed the manager and supervisor at Bumdes X, it was found that there are another chains to organize WCO. The other WCO chains are classified illegal because the reprocessed WCO are back to food chain. This research didn't pursue the illegal chains because of the limited information resources.

BCR Analysis to the Existed WCO Chains. BCR method was used to analysis the existed WCO chains. The data were obtained to analyze from households until manufacturer of multi-national company. The BCR method used present worth.

1. The households' BCR

The cost data to households used assumption that each family is using one liter cooking oil every week [22]. The cost for one liter cooking oil in August 2018 was Rp 11.000 so the cost for one month cooking oil was Rp 44.000. For a month, the need of cooking oil from each family is four liters. The households can sell it to waste bank and get Rp 2000 per liter. The WCO that came from household is one liter for one month, thus this data became benefit.

$$BCR_{household} = \frac{Benefit}{Cost} = \frac{2.000}{44.000} = 0,045 \tag{2}$$

2. Suronatan, Kauman, Karangjajen, Kotagede, and Suryadiningratan waste banks' BCR

The five waste banks bought the WCO from household for Rp 2.000 then this data became cost. The estimated collection WCO for each waste bank is 28 liters per month. The WCO is sold to Bumijo waste bank for Rp 3000 per liter, thus this data became benefit.

$$BCR_{five\ waste\ banks} = \frac{Benefit}{Cost} = \frac{(3000 \times 28) - (2000 \times 28)}{(2000 \times 28)} = 0,5 \tag{3}$$

3. Bumijo waste bank's BCR

Bumijo waste bank purchased WCO from the other waste banks for Rp 3.000 per liter. Bumijo can collect 200 liters per week. WCO that came from the other waste banks then filtered using soft fabric material then sold it to Bumdes X. Bumijo need to transport the filtered WCO and the distance between its place to Bumdes is 7,1 km. The fuel for transporting vehicle need one liter gasoline and the price for gasoline in August 2018 was Rp 6.550. One liter gasoline can be used for 30 km so the need for 7,1 km is Rp 1.550. The resume of costs for Bumijo waste bank can be found in Table 1. The benefit for Bumijo waste bank when sold the WCO for Rp. 4.500 to Bumdes X then its gained Rp 900.000 per week.

Table 1. The resume of costs for Bumijo waste bank

No	List of Costs	Amount	The cost for every unit for every amount	Total
1	WCO purchased	200 liters	Rp3.000	Rp600.000
2	Jerry can for 20 liters	10	Rp20.000	Rp200.000
3	Transportation fuel	1 times transport	Rp1.550	Rp1.550
4	Soft fabric clothing	1 meter	Rp12.500	Rp12.500

Bumijo waste bank has already reprocessed WCO with simple filtering method from 2014 until the data taken in August 2018. So, the waste bank operates for 56 months. There is depreciation in its tools, with assumption using Straight Line Depreciation (SLD). The formula for SLD is [21]:

$$SLD = \frac{B-S}{N} \tag{4}$$

Where, B = the cost of asset,
 S = salvage value of asset,
 N = depreciable life.

The depreciated assets for Bumijo waste bank are jerry cans and soft fabric clothing. The depreciation for both assets were:

$$SLD_{jerry\ can} = \frac{20.000-0}{20} = 1000 \tag{5}$$

$$SLD_{soft\ fabric\ clothing} = \frac{12.500-0}{10} = 1250 \tag{6}$$

Because Bumijo waste bank has already operated for 56 month or 4,7 years so the deprecation for each asset must be equal. The deprecation for jerry can for 4,7 years was Rp 4.700 and for soft fabric clothing was Rp 5.875.

$$BCR_{Bumijo\ waste\ bank} = \frac{(900.000 \times 4) - ((600.000 \times 4) + (1.550 \times 4) + (200.000 - 4700) + (12.500 - 5875))}{(600.000 \times 4) + (1.550 \times 4) + (200.000 - 4700) + (12.500 - 5875)} = 0,38 \tag{7}$$

4. Bumdes X’s BCR

Bumdes X has a little complex processes for filtering WCO. There are three steps for filtering processes in Bumdes X. First step is to filter the WCO with soft fabric clothing into box, the box capacity is 130 liters. Second, filtrated WCO from first step is pumped into drum with capacity is 200 liters. In the drum, WCO is filtered again using canvas fabric material. The last step, WCO is pumped again into 3 filtering tools that used carbon fiber. After that, filtrated WCO is pumped into storage drums with 1.000 liters’ capacity. Every month, Bumdes X is transported 10.000 liters filtrated WCO to manufacturer of multi-national company. Bumdes X sold the filtrated WCO for Rp 7.250. Then, the benefit for Bumdes X was Rp 72.500.000 per month. The list of costs for Bumdes X can be found in Table 2. Bumdes X has operated from 2014 so until August 2018, it has operated for 56 months.

Table 2. The Resume Costs for Bumdes X

No	List of Costs	Amount	The cost for every unit for every amount	Total
1	Container Box 130 l	2	Rp129.000	Rp258.000
2	Plactic Drum 200 l	1	Rp210.000	Rp210.000
3	Housing Filter Air Nanotec 10 inch	3	Rp60.000	Rp180.000
4	Cartridge filter 10" sediment dewater 5 micron	3	Rp17.500	Rp52.500
5	Storage container 1000 l	1	Rp1.500.000	Rp1.500.000
6	Water pump	2	Rp610.000	Rp1.220.000
7	PVC pipe 1,5"	10 m	Rp8.500	Rp85.000
8	Worker salary	1 person	Rp1.500.000	Rp1.500.000
9	Canvas fabric	1 m	Rp31.000	Rp31.000
10	Soft fabric clothing	1 m	Rp12.500	Rp12.500
11	WCO purchased	10000 l	Rp4.500	Rp45.000.000
12	Electric energy source	-	-	Rp122.000
13	Transportation	-	-	Rp350.000
Total of All Costs before Depreciation				Rp50.521.000

There are some of Bumdes X’s depreciated assets. Thus, the depreciation was using SLD. The data of SLD depreciation of each asset can be found at Table 3. The total cost for the assets that

didn't have depreciation was Rp 47.024.500. Therefore, the total cost for all assets is Rp 49.444.700.

Table 3. Resume of SLD from each asset

No	List of Costs	B	S	N (years)	SLD (per year)/amount	SLD for 4,7 year	Cost after depreciation
1	Container Box 130 l (2)	Rp129.000	Rp0	20	Rp6.450	Rp30.315	Rp197.370
2	Plactic Drum 200 l	Rp210.000	Rp0	20	Rp10.500	Rp49.350	Rp160.650
3	Housing Filter Air Nanotec 10 inch (3)	Rp60.000	Rp0	10	Rp6.000	Rp28.200	Rp95.400
4	Storage container 1000 l	Rp1.500.000	Rp0	25	Rp60.000	Rp282.000	Rp1.218.000
5	Water pump (2)	Rp610.000	Rp15.000	10	Rp59.500	Rp279.650	Rp660.700
6	PVC pipe 1,5" (10 m)	Rp8.500	Rp0	20	Rp425	Rp1.998	Rp65.025
7	Canvas fabric (1 m)	Rp31.000	Rp0	10	Rp3.100	Rp14.570	Rp16.430
8	Soft fabric clothing (1 m)	Rp12.500	Rp0	10	Rp1.250	Rp5.875	Rp6.625
Total Cost after Depreciation							Rp2.420.200

Therefore, BCR for Bumdes X was:

$$BCR_{Bumdes X} = \frac{Benefit}{Cost} = \frac{72.500.000 - 49.444.700}{49.444.700} = 0,47 \quad (8)$$

The BCR for each stakeholder in the existed WCO chains were less than 1 but still positive. Eschenbach [20] clarified that the project has BCR less than 1 so the project is unattractive because the cost is more than benefit. The reasons of BCR was fall behind 1 were the limited information about intangible benefits from WCO chains. The BCR calculation for existed WCO chains was only rely on tangible benefits. There was a consideration if the research had tried to explore illegal manufacturers' data, the intangible benefits could be obtained.

Conclusions

The WCO chains in Yogyakarta city has involved households, waste banks, Bumdes X and manufacturer of multi-national company. The identification for WCO chains was initiated when waste banks collected WCO for households in their area. The existed and explored WCO chains had boundary to Yogyakarta city and pursued the visible chains. Although, all WCO chains were categorized as hidden because there are illegal chains that take back WCO to food chain.

The BCR for this existed WCO chains was less than one but the ratio was still positive. The calculation of BCR had only taken tangible benefits. The consideration of intangible benefits must be

taken to explore the added value of WCO chains into energy source. For further research, the data of illegal chains can be obtained and intangible benefits can be calculated.

References

- [1] Information on <https://dsposal.uk/ewc-codes/20/20-01/20-01-25/>
- [2] H.M. Wee, S.D. Budiman, L.C. Su, M. Chang and R. Chen: Responsible supply chain management – an analysis of Taiwanese gutter oil scandal using the theory of constraint. *International Journal of Logistics Research and Applications* Vol. 19 (2016) Issue 5, p. 380-394
- [3] Peraturan Pemerintah Republik Indonesia Nomor 81 Tahun 2012 tentang Pengelolaan Sampah Rumah Tangga dan Sampah Sejenis Sampah Rumah Tangga
- [4] Peraturan Menteri Negara Lingkungan Hidup Republik Indonesia Nomor 13 Tahun 2012 tentang Pedoman Pelaksanaan Reduce, Reuse, dan Recycle melalui Bank Sampah
- [5] Peraturan Daerah Kota Yogyakarta Nomor 18 Tahun 2002 tentang Pengelolaan Kebersihan
- [6] Information on https://kotabogor.go.id/index.php/show_post/detail/74/bplh-kota-bogor-taretkan-96-ribu-literminyak-jelantah-terkumpul-setahun
- [7] Haruhiro Fujita, Koji Okuhara, Katsuyuki Nakano and Hiroe Tsubaki: Environmental Analyses of Waste Cooking Oil Recycling and Complete Use Practices in Bogor, Indonesia. *International Conference on Technology, Informatics, Management, Engineering & Environment* (2013), p. 28-31
- [8] Abdulkarim Ali Deba, Hamzat Ibiyeye Tijani, Ahmed Ibrahim Galadima, Bashir Sajo Mienda, Fatima Aliyu Deba and Laila M. Zargoun: Waste Cooking oil: A Resourceful Waste for Lipase Catalysed Biodiesel Production. *International Journal of Scientific and Research Publications* Vol. 4 (2014) Issue 9, p. 1-12
- [9] Wen-Tien Tsai: Mandatory Recycling of Waste Cooking Oil from Residential and Commercial Sectors in Taiwan. *resources* Vol. 8 (2019) Issue 1, 38, p. 1-11
- [10] Wan Nur Aifa Wan Azahar, Mastura Bujang, Ramadhansyah Putra Jaya, Mohd Rosli Hainin, Azman Mohamed, Norzita Ngadi and Dewi Sri Jayanti: The Potential of Waste Cooking Oil as Bio-Asphalt for Alternative Binder – An Overview. *Jurnal Teknologi* Vol. 78 (2016) No. 4, p. 111-116
- [11] Gemma Toop, Sacha Alberici, Matthias Spoettle and Huygen van Steen: *ECOFYS: Trends in the UCO Market* (ECOFYS UK Ltd, London 2013)
- [12] Arjun B. Chhetri, K. Chris Watts and M. Rafiqul Islam: Waste Cooking Oil as an Alternate Feedstock for Biodiesel Production. *energies* Vol. 1 (2008) Issue 1, p. 3-18
- [13] Claudia Sheinbaum, Marco V Balam, Guillermo Robles, Sebastian Lelo de Larrea and Roberto Mendoza: Biodiesel from waste cooking oil in Mexico City. *Waste Management & Research* Vol. 33 (2015) Issue 8, p. 1-10
- [14] Ridvan Arslan and Yahya Ulusoy: Utilization of waste cooking oil as an alternative fuel for Turkey. *Environmental Science and Pollution Research* Vol. 25(2018) Issue 25, p. 24520-24525
- [15] Huiming Zhang, U.Aytun Ozturk, Qunwei Wang and Zengyao Zhao: Biodiesel produced by waste cooking oil: Review of recycling modes in China, the US and Japan. *Renewable and Sustainable Energy Reviews* Vol. 38 (2014), p. 677-685

- [16] Jinmei Yang, Takeshi Fujiwara and Qijin Geng: Life cycle assessment of biodiesel fuel production from waste cooking oil in Okayama City. *Journal of Material Cycles and Waste Management* Vol. 19 (2017) Issue 4, p. 1457-1467
- [17] Aldara da Silva César, Dayana Elizabeth Werderits, Gabriela Leal de Oliveira Saraiva and Ricardo César da Silva Guabiroba: The potential of waste cooking oil as supply for the Brazilian biodiesel chain. *Renewable and Sustainable Energy Reviews* Vol. 72 (2017), p. 246-253
- [18] Elisabet Vinyes, Jordi Oliver-Solà, Cassia Ugaya, Joan Rieradevall and Carles M. Gasol: Application of LCSA to used cooking oil waste management. *The International Journal of Life Cycle Assessment* Vol. 18 (2013) Issue 2, p. 445-455
- [19] Rowland Atkinson and John Flint: *Accessing Hidden and Hard-to-Reach Populations: Snowball Research Strategies* (social research update, University of Surrey, Guildford 2001)
- [20] Ted G. Eschenbach: *Engineering Economy: Applying Theory to Practice Third Edition* (Oxford University Press, New York 2011)
- [21] Donald G. Newnan, Ted G. Eschenbach and Jerome P. Lavelle: *Engineering Economic Analysis 9th Edition* (Oxford University Press, New York 2004)
- [22] Medeline Citra Vanessa and Jihan Mutia F. Bouta: *Analisis Jumlah Minyak Jelantah yang Dihasilkan Masyarakat di Wilayah Jabodetabek.* (2016)