WHITE PAPER

SEPTEMBER 2018

THE POTENTIAL ECONOMIC, HEALTH AND GREENHOUSE GAS BENEFITS OF INCORPORATING USED COOKING OIL INTO INDONESIA'S BIODIESEL

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ACKNOWLEDGMENTS

Kharina and Searle are with the International Council on Clean Transportation. Rachmadini, Kurniawan, and Prionggo are with Yayasan Koaksi Indonesia.

This study was funded through the generous support of the Norwegian Agency for Development Cooperation and The David and Lucile Packard Foundation. Thanks to Ray Minjares and Nic Lutsey for helpful reviews.

The authors are grateful for contributions from the following: Endra Setyawan, Director, Lengis Hijau Foundation; Andy Hilmy Mutawakkil, Co-Founder/Owner, CV. Garuda Energi Nusantara/Genoil; Matias Tumanggor, Chairman, Association of UCO Collectors for New and Renewable Energy (APJETI); Adiwiyarso, Manager, Pangkep 33 Restaurant, Serpong, South Tangerang; Dirham Karel, General Manager, PT Inovasi Kuliner Indonesia (Shaburi Restaurant); Putu Agus Budiana, Head of Bali Province Energy Agency, Bali Provincial Government, Energy Agency (Dinas Energi); Dewa Suteja, Staff of Division III (B3 Waste Management), Denpasar City Government, Environment & Cleanliness Agency (Dinas Lingkungan Hidup & Kebersihan); Latifah Hanum, Head of Technical Development Section of Environment and Cleanliness, Jakarta Provincial Government, Environment and Cleanliness Agency; Setiawati, Head of Partnership and Capacity Building Section, Bogor City Government, Environment Office; Jimmy VP Hutapea Head of Public Transportation Division, Transportation Office of Bogor Municipality, Bogor City Government, Transportation Office; and Agus Suprarto, Secretary, Transportation Office of Bogor Municipality, Bogor City Government, Transportation Office.

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EXECUTIVE SUMMARY

Indonesia has one of the most ambitious biofuel policies in the world. Currently, all diesel fuel used for land vehicles must have 20% bio-content. By 2020, that mandate will increase to 30%. At the same time, through its first Nationally Determined Contribution (NDC), the country committed to reduce its greenhouse gas (GHG) emissions 26% below business-as-usual (BAU) levels by 2020 and reduce them 29% below BAU by 2030. The biodiesel Indonesia uses to meet its mandate comes exclusively from palm oil, which increases GHG emissions when compared to petroleum and is linked to deleterious outcomes for ecosystems, including deforestation and loss of biodiversity.

Diversifying its biofuel mix by developing other, more sustainable feedstocks could help Indonesia balance its biofuel blending targets and its environmental commitments. This study assesses the opportunity to increase the collection and use of used cooking oil (UCO) for biofuel production in Indonesia. This research builds upon previous works that assessed the potential availability of used cooking oil, specifically in Greater Jakarta, also known as Jabodetabek. In this work, we present newer data collected from interviews with UCO biofuel producers and government officials as well as a literature review to estimate the total UCO biodiesel potential nationally. We also analyze the economics of UCO biodiesel production in the Indonesian context and assess the total national GHG benefits from using UCO for biodiesel.

Cooking oil consumption is high in Indonesia, and there is no existing, systematic effort to collect and repurpose UCO for other uses. While some of collected UCO is refined into biodiesel, the rest is exported, reused as "new" cooking oil with negative public health impacts, or disposed of in soil and wastewater, contributing to other environmental problems.

UCO collection could be expanded to cover all urban restaurants and other concentrated UCO sources with feasible public initiatives (Table ES 1). This amount could make modest, but meaningful, contributions to Indonesia's biofuel blending and GHG reduction goals. With more intensive public initiatives to establish effective household collection programs, Indonesia could collect enough UCO to produce 1.2 billion liters of biodiesel annually. This means Indonesia could replace 45% of its current consumption of palm biodiesel with waste oil, saving around 6 million tonnes of carbon dioxide equivalent (CO_2e) annually. Although the collection of UCO at this level would be challenging, we find this is just 50% of the total production of UCO, which we estimate amounts to more than 3 billion liters per year.

Table ES 1. Potential biodiesel production and GHG emission savings from UCO in Indonesia.

Category	Used cooking oil amount (million liters/year)	Potential palm biodiesel displacement (million liters/year)	Percent of palm biodiesel that could be displaced with used cooking oil	Potential GHG emission savings (million tonnes of CO_2e)
Currently collected	0.9			
Easy to collect (urban restaurants, etc.)	157	121	4%	0.6
More challenging to collect (urban restaurants and households)	1,638	1,261	45%	6.2
Technical potential (total production)	3,072	2,366	84%	11.5

GHG = Greenhouse gas; CO_2e = Carbon dioxide equivalent

Indonesia could also reduce government expenditures on the biofuel mandate by providing a fraction of its biodiesel subsidy funds to UCO biodiesel, instead of to palm biodiesel. Our analysis finds that UCO biodiesel in Indonesia has a much lower production cost than palm biodiesel. We estimate that subsidizing biodiesel produced from all UCO produced at urban restaurants would save the government 345 billion rupiah per year compared to subsidizing the same amount of palm biodiesel. In addition, supporting UCO biodiesel may result in savings in other sectors, such as public health and water and soil conservation. Indonesia can leverage lessons learned from previous domestic collection efforts, as well as from existing programs around the world, to support utilization of this cost-effective, low-carbon resource.

1. INTRODUCTION

For more than a decade, Indonesia has been promoting the use of biofuels. The main goal is to reduce the country's dependence on oil imports, but also to support the domestic agricultural economy and to mitigate climate change. In 2008, the Ministry of Energy and Mineral Resources (MEMR) adopted Indonesia's first biofuel blending mandate, MEMR Regulation No. 32/2008. Since then, Indonesia has ramped up its efforts to promote biofuels by increasing its biofuel blend targets as well as providing biofuel subsidies to producers. Currently, Indonesia imposes a 20% biodiesel blending mandate on the transportation sector, locally referred to as the B20 program. Table 1 presents the Indonesian biofuel mandate per MEMR Regulation No. 12/2015, the second amendment to the 2008 mandate.

Table 1. Indonesian biodiesel mandate, according to MEMR No. 12/2015, showing percent of biofuel blending required.

Sector	April 2015	January 2016	January 2020 and later
Microbusiness, fisheries, agriculture, and public service (subsidized) **Transportation** **Industry and commercial**	15%	20%	30%
Electricity	25%	30%	30%

The biodiesel Indonesia uses to meet its national mandate comes exclusively from palm oil. Over the last few decades, oil palm expansion in Indonesia has been one of the major drivers of deforestation and biodiversity losses and has resulted in other negative ecological impacts (Petrenko, Paltseva, & Searle, 2016). Much of the palm oil plantations that replaced tropical rainforests also eradicated carbon-rich peat soils. The destruction of peatland releases large amounts of CO_2 into the atmosphere, which contributes to high land use change emissions of palm biodiesel. These emissions have been shown to exceed the CO_2 emission benefit of displacing conventional diesel fuel with palm biodiesel. In fact, land use change results in a net increase in Indonesia's CO_2 emissions (Kharina & Searle, 2016). Similarly, regulatory analyses performed for biofuel policies in other countries consistently find that palm biodiesel drives very high emissions from land use change, resulting in higher GHG emissions overall than those from petroleum-derived fuels (Valin et al., 2015; CARB, 2014). It is clear that Indonesia's biofuel policies are counterproductive to the country's goal of reducing CO_2 emissions by 26% relative to a business-as-usual (BAU) scenario by 2020 (Government of Indonesia, 2016).

Biodiesel from some types of waste can be more environmentally friendly than those made from food crops, such as palm oil, when those wastes are not used or are underutilized. Many countries and jurisdictions, such as the United States, the state of California, and the European Union promote industry development and the use of biofuels derived from waste, including used cooking oil (UCO). UCO is abundant in Indonesia and is underutilized. In addition, UCO is a low-cost feedstock requiring relatively simple processing to convert it into biodiesel.

The national consumption of cooking oil in Indonesia is substantial, accounting for about 3.4 billion liters in 2017 (BPS, n.d.), yet the UCO biodiesel industry in Indonesia is very small. In early 2018, there were fewer than ten known UCO biodiesel producers in Indonesia with an estimated total annual capacity of 5.3 million liters. This figure is miniscule compared to the 2.8 billion liters of palm oil biodiesel consumed nationally in 2017 (Wright & Rahmanulloh, 2017). A non-exhaustive list of these producers is presented in Appendix A. Some of these facilities are producing below capacity, due to a limited supply of feedstock. One known producer, Lengis Hijau, has the ability to produce 1.1 million liters annually, but produces an average of 572,000 liters each year. Another producer, Genoil, which has an annual capacity of 1.46 million liters, produces only 511,000 liters of UCO biodiesel per year. The government of Indonesia does not maintain a list of UCO biodiesel producers in Indonesia and, overall, there is not a deep understanding of the national potential for the UCO biodiesel industry.

This study presents new information regarding current UCO collection, its use in Indonesia, and the potential for UCO to contribute to Indonesia's biodiesel policies as well as its CO_2 emission reduction goals. The information presented in this study is sourced from literature reviews and from interviews with restaurants, UCO biodiesel producers, and local government officials.

2. ASSESSMENT OF UCO POTENTIAL

2.1. CURRENT UCO COLLECTION AND UCO BIODIESEL PRODUCTION

At present, there is no centralized UCO collection system in Indonesia at the national or regional level. The majority of UCO comes from hotels, restaurants, and households that either sell their UCO to collectors or dispose of it down drainpipes or as part their municipal waste collection. UCO collectors resell it to exporters, biofuel producers, recyclers, or other UCO repurposing industries. Exporters sell collected UCO to countries, such as South Korea, Germany, United Kingdom, the Netherlands, the United States, and Pakistan (M. Tumanggor, private communication, November 10th, 2017). Recycled UCO is generally resold as cooking oil, mainly to price-sensitive consumers, such as street food vendors and low-income households. UCO from households, on the other hand, is generally not collected. The typical UCO supply chain in Indonesia is presented in Figure 1.

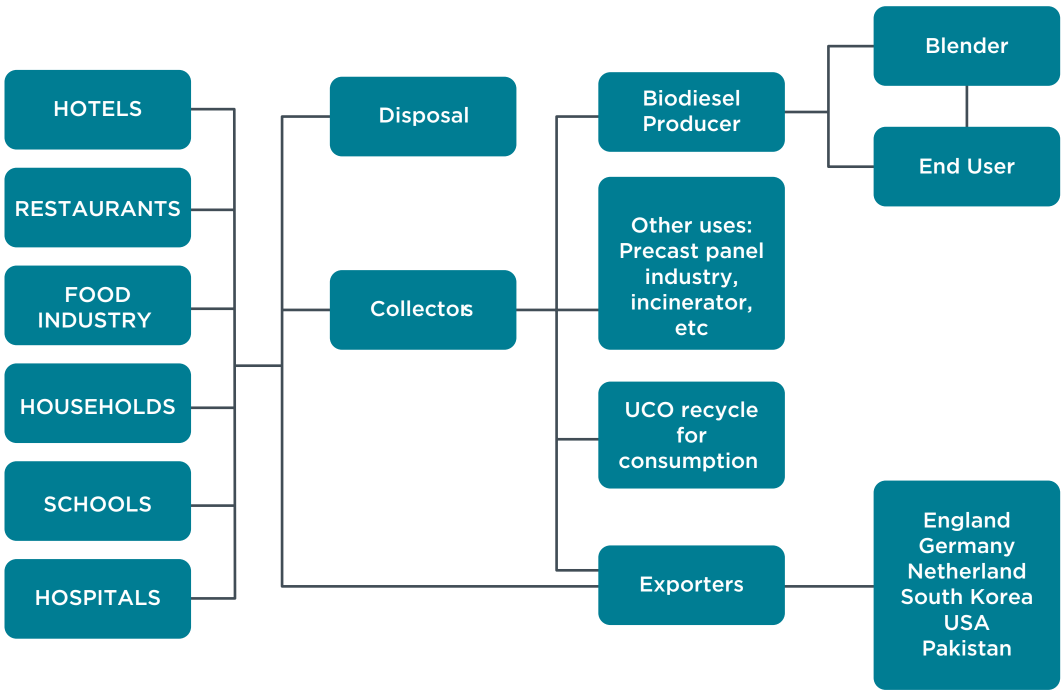

Figure 1. UCO supply chain in Indonesia.

Based on a few interviews conducted with restaurant managers and UCO collectors, we learned that collectors usually approach restaurants or businesses to collect their UCO, and not vice versa. Many UCO collectors have an agreement in place with their sources on quantities and prices, but there is generally no agreement on the quality of UCO (M. Tumanggor, personal communication, November 10, 2017). Collectors typically take all the UCO they can get, even though it is more challenging to produce a high-quality product when using poor-quality UCO.

Comprehensive data is not available regarding UCO collection in Indonesia. Table 2 is a summary of the few data points available for businesses, schools, and households in Jabodetabek (Greater Jakarta, comprising Jakarta, Bogor, Depok, Tangerang, and Bekasi). Table 2 also includes estimates of current UCO collection in other cities for which data is available, including Bali and Makassar. The actual collection amount is likely to be higher than presented here.

Table 2. UCO collection in Indonesian cities.

City	Producer type	Annual UCO collection (KL)	Number of establishments surveyed	Source
Jabodetabek	Restaurants			
	Pangkep 33	6.5	4	A. Adiwiyarso (personal communication, November 28, 2017)
	Kentucky Fried Chicken	53.5	180	Clean Carbon Indonesia (2013)
	McDonald's	8	3	Clean Carbon Indonesia (2013)
	Ayam Suharti	11.7	3	Clean Carbon Indonesia (2013)
	Bebek Selamet	43.2	5	Clean Carbon Indonesia (2013)
	Schools	62.4	20	Clean Carbon Indonesia (2013)
	Hospitals	3.6	4	Clean Carbon Indonesia (2013)
	Households	0.8	188	Fujita et. al. (2015)
	Jabodetabek total	**189.7**		
Bali	Hotels and restaurants	156	N/A	E. Setyawan (personal communication, November 24, 2017), Christensen (2012)
Makassar	Hotels, restaurants, and the food industry	547.5	N/A	A. Mutawakkil (personal communication, November 16, 2017), Aria (2016)
	TOTAL	**893.2**		

2.2. POTENTIAL FOR INCREASING UCO COLLECTION

While it appears that relatively small volumes of UCO are currently collected in Indonesia, there is high potential to increase UCO collection and usage in biodiesel. In this section, we review government efforts to increase UCO collection and estimate how much could be collected with more government initiatives or with a UCO price increase.

Some regional governments have begun to support increased UCO collection. The provincial government of DKI Jakarta has created initiatives through Governor Regulation No. 167/2016 to manage UCO waste and increase UCO collection for biodiesel. This is the first provincial-level regulation in Indonesia that regulates UCO. UCO producers, which are defined in the regulation as restaurants, hotels, food industry, and "other businesses," are obligated to reuse UCO in non-food uses or supply it to collectors or other beneficiaries (e.g. biodiesel producers). According to the regulation, UCO is not allowed to be reused for consumption or thrown away.

The provincial government of DKI Jakarta plans to issue a technical regulation in 2018 to implement the governor's regulation. The government also plans to conduct widespread socialization of the governor's regulation with various stakeholders, especially UCO producers. Specific steps include a program blueprint, a socialization roadmap (both internally and externally), a one-stop licensing service, and an implementation standard. In the future, the government envisions a system in which all UCO sources, including hotels and restaurants, would be required to submit a periodic report on their UCO management. All UCO collecting parties must also have a business license and be registered. This program would also allow households to receive payment for UCO delivered to waste banks (L. Hanum, personal communication, November 16, 2017).

Bali is following Jakarta's steps. According to Denpasar City Government staff D. Suteja (personal communication, November 23, 2017), the city is developing a Mayor's Regulation that would include a mandate for all hotels and restaurants to supply their UCO to officially licensed biodiesel producers.

It is clear that there is great potential to increase UCO collection. PT Clean Carbon Indonesia (2013) published a fairly comprehensive report on the UCO potential in the Jakarta area. The report estimates that a total of 26 kiloliters and 2,540 kiloliters per year of UCO could be collected from hospitals and schools in the Jakarta area, respectively. Another data point comes from Christensen (2012), who quotes survey results from the firm Caritas Switzerland, which estimates that hotels and restaurants on the island of Bali have the potential for supplying 16.6 kiloliters of UCO per week. From these numbers, we estimate the rate of potential UCO collection per capita from hotels and restaurants and extrapolate to all Indonesian cities, using population data from the Ministry of Home Affairs, according to the ministerial regulation No.137/2017. We estimate the potential UCO availability from these sources to be 156,618 kiloliters annually (Table 3). If collected, this amount of UCO would be enough to supply more than 100% of the current UCO biodiesel producer capacity in the country. The number does not include UCO from food production facilities, such as catering businesses, hypermarkets, and factories producing chips and other snacks. As one example, 43 branches of Carrefour Hypermart have supplied 14.4 kiloliters of UCO per year to the government of Bogor as part of a UCO biodiesel program (Kusuma, 2013).

Even greater amounts of UCO could be collected from households in Indonesia compared to commercial sources. These domestic sources offer better-quality UCO compared to that collected from hotels, restaurants, and other businesses (Li and Yu, 2015). Better-quality UCO produces higher-quality biodiesel with better yield (the ratio of biodiesel produced to the amount of feedstock used) than lower-quality UCO.

We estimate the national potential for UCO collection from urban households. According to a survey conducted by Fujita, et.al. (2015), each household in Bogor city produces about 0.8 liter of UCO per month. We extrapolate this finding to the entire country, combined with data on population and household size. The Indonesian population living in cities in 2015 is estimated to be around 140 million people, comprising 53.5% of the national population, according to BPS (2017). BPS also reports that an average household consists of 3.9 people. From this, we estimate there are 35.8 million households in Indonesian cities, and 67.2 million nationwide. We assume that UCO collection from rural households would be substantially more difficult, and more expensive, than collection from urban households. Assuming that UCO is only collected from urban households, it is estimated that more than 1.6 million kiloliters of UCO can be obtained (Table 3).

Table 3. UCO collection in Indonesia, current and potential.

Category	UCO amount (kL/yr)	Description
Currently collected	893	
Easy to collect	156,618	Potential UCO production from restaurants, hotels, schools, and urban hospitals
More challenging to collect	1,638,111	Potential UCO production from restaurants, hotels, schools, hospitals, and urban households
Technical potential	3,072,280	Potential UCO production from all sources nationwide

2.3. ECONOMICS OF UCO BIODIESEL

This section attempts to estimate the average price and cost of producing UCO biodiesel and the resources the Indonesian government would need to support it as much as they have supported palm biodiesel.

As part of the B20 program, the government of Indonesia subsidizes palm biodiesel for transportation using monies collected from the Indonesian Oil Palm Estate Fund (BPDP-KS). Pertamina, a state-owned oil and gas company, and AKR Corporindo, a publicly held company, are the only two companies licensed to distribute subsidized diesel fuel in the country. MEMR directly appoints a number of biodiesel producers to provide certain volumes of biodiesel to specific oil depots operated by Petamina or AKR Corporindo. For example, MEMR Regulation No. 3756/2017 requires 1.4 million kiloliters of unblended biodiesel sold by 20 designated biodiesel producers to be blended with subsidized diesel fuel and shipped to end users by designated distributors – Pertamina and AKR Corporindo – from November 2017 to April 2018. To predetermine the amount of subsidy given to these biodiesel producers, MEMR issues a monthly biofuel market index price, which is a sum of the previous month's Crude Palm Oil (CPO) price, $100 USD/tonne to account for the cost of converting CPO to biodiesel, and a region-specific transport fee. Once a subsidy is calculated—by finding the difference between the biofuel market index price and the conventional diesel price—it's provided to the designated biodiesel producers to enable them to cover their production costs. In comparing the cost of palm biodiesel and CPO biodiesel in this report, we refer to the market price index for March 2018 according to EBTKE letter No.1179/2018.

Although this subsidy program is well-instituted for palm biodiesel, it has not been implemented for UCO biodiesel to date. The remainder of this section analyzes UCO biodiesel production economics and estimates the amount of subsidy that would be provided to a typical UCO biodiesel producer, if it were eligible.

Table 4 summarizes the available information on UCO prices by city and type of buyer in Indonesia. Although the data spans a few years, there does not appear to be a price discrepancy between regions. This corroborates the finding by Clean Carbon Indonesia, PT (2013) of similar prices countrywide for UCO. UCO exporters may offer higher prices compared to other buyers.

Table 4. UCO price by location in Indonesia.

Location	Buyer	UCO Price (IDR per liter)	Source
Jakarta	Collector	3,000–4,700	Clean Carbon Indonesia (2013), M. Tumanggor (personal communication, November 10, 2017)
	Exporter	7,000	M. Tumanggor (personal communication, November 10, 2017)
Bogor	Biodiesel producer	3,500–4,250	Setiawati (personal communication, November 29, 2017), Arifenie (2011), & Fujita et.al. (2015)
East Java	Biodiesel producer	3,500–7,000	Arifenie (2011)
Bali	Biofuel producer	2,500	E. Setyawan (personal communication, November 24, 2017)
	Exporter	5,000	
	Animal feed producer	6,000–7,000	
Makassar	Biofuel producer	3,500	A.H. Mutawakkil (personal communication, November 16, 2017)

Table 5 presents cost estimates of UCO biodiesel production in Indonesia. Because the process to produce biodiesel is the same whether using palm oil or UCO, we assume the same conversion cost for UCO as for palm oil, as estimated by the government. All conversions between U.S. dollar and Indonesian rupiah in this calculation are based on historical exchange rates between the Indonesian Rupiah (IDR) and the U.S. Dollar (USD) between September 10, 2017, and March 7, 2018.[1]

UCO may require pretreatment before it can enter the biodiesel production process. Like palm oil and other crude vegetable oils, UCO contains impurities, including free fatty acid (FFA) and water. High FFA content in biodiesel feedstock may compromise transesterification, the process to convert oils and fats to biodiesel, resulting in a reduced biodiesel yield and low-quality product (Elliott, 2008; Fenanangad et.al., 2015; Li and Yu, 2015). Indonesian CPO biodiesel producer Lengis Hijau reported the need to add purifying compounds to UCO to remove impurities before processing into biodiesel (E. Setyawan, personal communication, November 24, 2017).

As demonstrated by Elliott (2008), biodiesel production from waste feedstocks with high FFA and water content is possible without pretreatment, but generally UCO purification may be preferable to ensure a high-quality biodiesel. We include the cost of pretreatment in our analysis, assuming a methanol solution and sulfuric acid are used to convert FFA before transesterification, as described in detail by Canakci and Gerpen (2001).

There is variation in reported UCO biodiesel yields. For example, 94% is quoted by Mandolesi de Araújo, de Andrade, de Souza e Silva, and Dupas (2013), while Canacki and Gerpen (2001) report a yield of 91%. In this analysis we refer to the GREET[2] model's yield value of 77%. This value is closer to values reported by Indonesian producers, ranging between 70% and 80% (Arifenie, 2011; Setiawati, personal communication, November 29, 2017).

1 https://www.exchange-rates.org/history/IDR/USD/T, accessed March 8, 2018

2 Yield value of 1.3, according to the GREET model developed by the California Air Resources Board (CARB, n.d.)

The biodiesel process produces glycerine as a by-product, which is relatively highly priced. Although not all UCO biodiesel producers consider this a sellable product, we consider it a potential source of income and estimate the value based on Malins (2017).

Table 5. Estimated cost to produce one liter of UCO biodiesel.

Expense	Price in idr	Source
Average UCO price for biofuel producers	3,781	Table 4
Pretreatement cost	686	Calculated according to report by Canakci & Gerpen (2001)
Biodiesel production cost	1,174	EBTKE Letter No. 1179/12/DJE/2018
Glycerine income	(340)	Malins (2017)
Total UCO biodiesel cost	**5,301**	**Calculated**

Referring to EBTKE Letter No.1179/ DJE/2018, the government of Indonesia set the palm biodiesel price at IDR 8,161 in March 2018. Assuming a price for subsidized diesel fuel (commonly called Public Service Obligation, or PSO) of IDR 5,150 per liter as reported by BPH Migas (2018) for February 2018, the biofuel subsidy for palm biodiesel amounts to IDR 3,011 per liter.

According to our analysis, the median cost of producing UCO biodiesel is approximately IDR 5,300 per liter, a cost that is 35% lower than producing palm biodiesel and is almost as low as the price of PSO diesel fuel. Subsidizing UCO biodiesel instead of palm biodiesel could save the Indonesian government IDR 2,860 per liter. This figure depends very much on the CPO market price, which varies monthly. As a comparison, the average palm biodiesel subsidy over the period January–October 2017 was IDR 4,054 per liter (Yuniartha & Laoli, 2017), costing the Indonesian Government 5.7 trillion rupiah during that period, or about 7.6 trillion rupiah annually. If UCO collection in Indonesia could be expanded to the “easy” sources listed in Table 3 (urban restaurants, schools, etc.) and this amount were subsidized for biodiesel production, reducing the need to subsidize palm biodiesel, the government could save around 345 billion rupiah per year. This amount does not account for the indirect savings that may arise from unclogged waterways, uncontaminated groundwater, and increased health risks arising from consuming UCO as “new” cooking oil.

Indonesia could also benefit from reducing UCO exports and using this resource domestically. We are unable to find information on the total amount of UCO exported from Indonesia specifically.

2.4. POTENTIAL PALM OIL DISPLACEMENT AND GHG BENEFITS

Replacing a fraction of Indonesia’s palm biodiesel with UCO biodiesel would carry substantial climate benefits, in addition to saving Indonesia’s government money on subsidies. Palm oil cultivation is associated with very high land-use change emissions from deforestation and peat drainage (Petrenko & Searle, 2016). According to Wright & Rahmanulloh (2017), Indonesia consumed 2.8 million kiloliters of biodiesel in 2017, all produced from palm oil. Based on our previous analysis, every tonne of UCO biodiesel that displaces palm biodiesel would avoid enough deforestation, peat drainage, oil palm production, and palm oil processing to save 4.9 tonnes of CO_2e (Kharina & Searle, 2016).

Using a conservative assumption of 77% for UCO biodiesel yields, we estimate the amount of palm oil that could be displaced and the associated GHG benefits in Table 4. The UCO that could be easily collected from restaurants, hotels, schools, and urban hospitals could displace 4% of national palm biodiesel consumption, saving about 588,000 tonnes of CO2e. UCO collected from urban households as well as urban restaurants, etc., could displace around 45% of palm biodiesel consumption, delivering around 6 million tonnes of CO_2e reduction. If all the potential UCO in Indonesia were collected and used for biodiesel production as part of Indonesia's B20 policy, it would displace about 2.4 billion liters of palm biodiesel annually. This amounts to 84% of Indonesia's 2017 national biodiesel consumption and would result in a savings of nearly 12 million tonnes of CO2e per year.

Table 6. Potential palm biodiesel displacement and GHG benefits.

Category	Used cooking oil amount (million liters / year)	Potential palm biodiesel displacement (million liters / year)	Percent of palm biodiesel that could be displaced with used cooking oil	Potential GHG emission saving (million tonnes of CO_2e)
Currently collected	0.9			
Easy to collect (urban restaurants, etc.)	157	121	4%	0.6
More challenging to collect (urban restaurants and households)	1,638	1,261	45%	6.2
Technical potential (total production)	3,072	2,366	84%	11.5

3. OTHER BENEFITS OF USING UCO IN BIODIESEL

3.1. ECOLOGICAL BENEFITS OF AVOIDING UCO DISPOSAL

There would be other environmental benefits from increasing UCO collection and using it in biodiesel. UCO that is not collected or reused is generally disposed of in drains, on the ground, or in landfills with negative ecological impacts on local waterways, groundwater, and soils. A survey by Vanessa & Bouta (2017) found that 51% of UCO from households in Tangerang, Indonesia, is discarded in municipal waste collection, 39% is dumped in the gutter or sewer, and 4% is dumped directly onto the ground. Similarly, Fujita et.al. (2015) reported that 51% of households in Bogor, Indonesia, dispose of their UCO in the gutter while 17% dump it onto the soil.

UCO poured down the drain or gutter ends up in local waterways and can cause blockages in plumbing. When disposed of in water bodies, UCO increases the level of organic pollutants in the water. Since these organic pollutants are biodegradable, aerobic degradation processes take place that consume oxygen dissolved in the water, resulting in a reduction of the oxygen level in the water. This in turn leads to lower water quality that could endanger animals and plants within water bodies (EPA, n.d.).

Oil and grease disposed of in landfills or dumped directly onto the soil potentially seeps deeper into the ground and into the surrounding groundwater. This has negative impacts on local vegetation and possibly local animals and insects. Thode Filho et.al. (2017) reported that UCO in the soil is toxic to earthworms and may cause changes in plant morphology.

3.2. HEALTH BENEFITS OF AVOIDING UCO REUSE IN FOOD

Increasing UCO collection for biodiesel production would also have health benefits. Based on a survey by Caritas Switzerland, as cited by Christensen (2012), 50-60% of used cooking oil produced in hotels and restaurants in Bali is reused in food. This corresponds to more than 9,000 liters of recycled UCO used for cooking in Bali every week. In another survey performed in Jabodetabek, 4%-15% of households give their UCO to their domestic workers as a way to dispose of their UCO (Fujita et.al.,2015; Vanessa & Bouta, 2017). Although there is no information regarding further use of UCO in this case, we can assume that at least a portion of UCO given to domestic workers is consumed in food.

Research showing detrimental effects of consuming used cooking oil is abundant. Repeated use of cooking oil increases the level of 4-hydro-2-trans-nonenal, or HNE, in the oil. HNE, a toxic substance easily absorbed in food, and is linked to many different neurodegenerative conditions, such as stroke, Alzheimer's, Parkinson's, and Huntington's diseases as evidenced by Kruman et.al. (1997) and corroborated by the University of Minnesota (2005).

Furthermore, consuming used cooking oil increases LDL ("bad" cholesterol) and reduces HDL ("good" cholesterol) (Adam et al., 2008). Increased LDL is directly linked to hypertension and together, they can increase the risk of cardiovascular diseases, as demonstrated by Egan, et.al. (2012), and Cicero, et.al. (2014) among other studies. Soriguer et.al. (2003) conclude that the risk of hypertension is positively and independently associated with the amount of used cooking oil intake. In addition, a study by Leong et.al. (2012) shows that UCO consumption may negatively affect the activity of blood pressure-regulating enzymes, further increasing the risk for heart disease. According to the Indonesian Ministry of Health (2017), coronary heart disease is the leading cause of death in Indonesia, costing the country 7.4 trillion rupiah annually.

The list of diseases linked to the consumption of UCO does not end there. Animal testing of UCO consumption by Venkata & Subramanyam (2016) and Srivastava et.al. (2010) show that increased consumption of UCO leads to damage in the gastrointestinal system as well as kidney and liver functions.

It is clear that reducing the consumption of UCO in food would have health benefits for Indonesia's population.

4. UCO COLLECTION PROGRAMS

4.1. BOGOR UCO BIODIESEL PROGRAM

Bogor is the only city that has attempted to run a UCO biodiesel program in Indonesia. From 2008 to 2015, the regional transportation company, Perusahaan Daerah Jasa Transportasi (PDJT), collaborated with the Bogor City Environmental Management Agency to run a biodiesel program using UCO. The city collected UCO from households, schools, government buildings, and businesses to convert into biodiesel, which was then supplied to the public Trans Pakuan buses. After a few years of UCO collection and biodiesel production, the Bogor City government tested the UCO and found that, in general, it was poor. The biodiesel produced from this UCO did not pass the national standard. In addition, UCO biodiesel appeared to cause damage to the Trans Pakuan buses (Setiawati, personal communication, November 29, 2017). The Bogor city program was discontinued in 2015.

It seems likely that the UCO collected in the Bogor program was of low quality and had high FFA content. The fact that the biodiesel produced from this UCO did not pass the national standard suggests that biodiesel producers did not pretreat their UCO before transesterification. As discussed in section 2, it is technically feasible and economically viable to pretreat UCO and produce high-quality biodiesel that would not damage vehicles. If anything can be learned from the Bogor experience, it is that UCO needs to be properly pretreated before it's used in biodiesel.

The Bogor UCO biodiesel program is an example of a good incentive from the government, but it might have been more successful with better implementation and oversight. Similar programs are currently running successfully, including those in the United States and Europe, where UCO pretreatment is recommended by governments as a best-practice to ensure that the biodiesel meets specifications (Tsoutsos & Stavroula, 2013). In the United States, 11% of all biodiesel produced in 2017 was produced from UCO (EIA, 2018).

4.2. POTENTIAL UCO INCENTIVES FOR INDONESIA

The UCO biodiesel industry in Indonesia is in its infancy, and government incentives are needed for it to be successful. UCO biodiesel producers in Indonesia currently face difficulties in securing high quality feedstock in sufficient amounts. They must compete for this resource with exporters and UCO recyclers for resale in the food industry.

Indonesia could make policy changes to better support the UCO biodiesel industry, such as promoting UCO collection, supporting refinery construction, and securing a market for the end product. Indonesia could consider examples of policy incentives in other countries. Some governments, such as the U.K. Food Safety Agency (n.d.), mandate that UCO collected from catering businesses be supplied to biodiesel producers, incinerators for the generation of electricity, or for other uses, such as in the oleochemical industry. Furthermore, E.U. Regulation No. 142/2011 only authorizes UCO to be converted into biodiesel at authorized plants. All E.U. countries, as well as the United States, support demand for UCO biodiesel by including UCO as an eligible feedstock in biofuel mandates (European Parliament & Council of the European Union, 2015; CARB, 2018; Regulation of Fuels and Fuel Additives, 2010). In each of these cases, the blending of

UCO biodiesel into diesel transport fuel receives greater incentives than most other biofuel feedstocks.

We suggest two primary policy approaches to help Indonesia achieve the UCO potential quantified in this report. The most important primary step is to explicitly incorporate UCO biodiesel into the B20—and soon to be, B30—program. Thus far, palm oil biodiesel producers comply with the biodiesel mandate in the transportation sector by contracting by Pertamina. This option is not available to UCO biodiesel producers. To sufficiently support the growing UCO biodiesel industry in Indonesia, UCO biodiesel producers need to be able to blend UCO with conventional diesel and to be able to sell it to Pertamina or other blenders as part of the Biodiesel National Mandatory Program. More specifically, UCO biodiesel producers should be added to the list of eligible producers able to blend their fuel with subsidized diesel fuel. Secondly, Indonesia could include UCO biodiesel in the biodiesel subsidy program, which would have the dual benefit of supporting the development of the UCO biodiesel industry as well as saving the government money. To do this, the government could set a separate price for UCO biodiesel or redefine the palm oil biodiesel price to be a generic biodiesel price.

The following policy steps could also help the fledgling Indonesian UCO biofuel industry to produce high-quality biodiesel to contribute to Indonesia's biodiesel mandate. Indonesia could set a standard for UCO biodiesel quality. A quality target to aim for may help biofuel producers control their UCO feedstock quality and refining process. It would also help to identify a certification process for UCO biodiesel production. Another measure would be to require registration and certification of UCO biodiesel producers. With these two certification processes in place, the government could more easily ensure robust UCO biodiesel quality should it incorporate UCO biodiesel into the biodiesel mandate program. Lastly, the government could establish an investment and training program for small-scale UCO biodiesel producers, especially in rural communities.

In addition, Indonesia could also consider policies used in other countries, such as mandating that collected UCO be supplied to non-food uses or providing targeted fiscal incentives for UCO biodiesel producers.

5. CONCLUSIONS

There is a clear opportunity for Indonesia to contribute towards its energy independence and climate mitigation goals, while saving money on its biofuels program. Indonesia produces large quantities of UCO, which is mostly wasted or reused in food with negative health impacts. Promoting and incentivizing UCO collection is a cost-effective way to diversify Indonesia's biofuel supply, while delivering health and environmental benefits.

There are precedents for UCO collection and utilization programs. The city of Bogor had a successful UCO collection program that fed into a biodiesel refinery that supplied biodiesel to a local public transportation company. The program was stopped for technical reasons, but it is clear that such a program is possible. By implementing lessons learned from the previous program, as well as best practices from successful programs abroad, Indonesia could successfully utilize UCO in biofuel.

One of the key drivers for successful UCO collection and biodiesel production is financial incentive. The production cost of UCO biodiesel is lower than that of palm-based biodiesel, but it is still more expensive to produce than conventional fuel and thus would require policy support. Providing some of the palm oil estate funds to UCO biodiesel would be the most effective way to encourage the uptake of UCO biodiesel production in Indonesia. The government of Indonesia could also ensure that the UCO biodiesel produced in the country would be consumed there by making it possible for UCO to be blended with conventional diesel and to be sold to Pertamina and other fuel blenders.

REFERENCES

Adam, S.K., Soelaiman, I.N., Umar, N.A., Mokhtar, N., Mohamed, N., & Jaarin, K. (2008). Effects of repeatedly heated palm oil on serum lipid profile, lipid peroxidation andhomocysteine levels in a post-menopausal rat model. *McGill Journal of Medicine*, *11*(2), 145-51

Aria, P. (2016, December 18). Genoil, used cooking oil that empowers fishermen and thugs. *Kontan.co.id*. Retrieved from https://katadata.co.id/berita/2016/12/18/genoil-jelantah-yang-berdayakan-preman-sekaligus-nelayan

Arifenie, F.N. (2011, December 23). Profit by turning used cooking oil into biodiesel. *Kontan.co.id.* Retrieved from http://peluangusaha.kontan.co.id/news/meraup-laba-dengan-menyulap-minyak-jelantah-menjadi-biodiesel-

Artha Metro Oil (n.d.). *About Us*. Retrieved from http://en.arthametrooil.co.id/about.html

Badan Pusat Statistik. (n.d.). *Average Weekly Consumption per Capita of Several Important Foodstuffs, 2007-2017*. Retrieved from https://www.bps.go.id/statictable/2014/09/08/950/rata-rata-konsumsi-per-kapita-seminggu-beberapa-macam-bahan-makanan-penting-2007-2017.html

Badan Pusat Statistik. (2016). *Distribution of Cooking Oil Commodity Trade in Indonesia*. Retrieved from https://media.neliti.com/media/publications/48268-ID-distribusi-perdagangan-komoditas-minyak-goreng-di-indonesia-2016.pdf

Badan Pusat Statistik. (November, 2017). *Trends of Selected Socio-Economic Indicators of Indonesia*. Retrieved from https://www.bps.go.id/publication/2017/12/26/a16e0adf07c32e5dc6ecfe83/perkembangan-beberapa-indikator-utama-sosial-ekonomi-indonesia-edisi-november-2017.html

BPH Migas. (2018). *Gas price at the pump per February 24, 2018*. Retrieved from http://www.bphmigas.go.id/harga-bbm-spbu/per-24-februari-2018

California Air Resources Board. *California GREET Model Version 3.0.* Retrieved from https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm

California Air Resources Board. (2014). *Proposed Re-adoption of the Low Carbon Fuel Standard Regulation [Staff report: initial statement of reasons for rulemaking; Appendix I: detailed analysis for indirect land use change]*. Retrieved from https://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15isor.pdf

Canakci, M. & Gerpen, J.V. (2001). A pilot plant to produce biodiesel from high free fatty acid feedstocks. *2001 ASAE Annual International Meeting Proceeding*. Sacramento, California.

Christensen, P. (2012). The problem of used cooking oil disposal Caritas Switzerland turns Bali's used cooking oil into biodiesel. *Bali Advertiser*. Retrieved from https://www.baliadvertiser.biz/cooking_oil/

Cicero, A.F., Rosticci, M., Baronio, C. et al, & Brisighella Heart Study Group. (2014). Serum LDL cholesterol levels and new onset of arterial hypertension: an 8-year follow-up. *European Journal of Clinical Investigation, 44*, 926–932. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/eci.12325

Clean Carbon Indonesia, PT. (2013). *Waste Oil Recycling for Biodiesel in Jakarta Region* [Report submitted to UK Climate Change Unit, The British Embassy, Jakarta].

Egan, B. M., Li, J., Qanungo, S., & Wolfman, T. E. (2013). Blood pressure and cholesterol control in hypertensive hypercholesterolemic patients. *Circulation*. Retrieved from https://doi.org/10.1161/CIRCULATIONAHA.112.000500

Elliot, B.E. (2008). *Process-Intensified Low-Cost Biodiesel Production Using Meat Rendering Waste, Greases, and Food Wastes*. Retrieved from U.S. EPA https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.highlight/abstract/8734/report/F

Environmental Protection Agency. (2010). *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule.* Retrieved from Government Publishing Office https://www.gpo.gov/fdsys/pkg/FR-2010-03-26/pdf/2010-3851.pdf

European Parliament, & Council of the European Union. (2015). *Directive (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 Amending Directive 98/70/EC Relating to the Quality of Petrol and Diesel Fuels and Amending Directive 2009/28/EC on the Promotion of the Use of Energy From Renewable Sources*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L1513&from=EN

Fenangad, D., Abon, J.E., Mabalot, P., & Orge, R. F. (2015). Production of biodiesel from waste cooking oil using the cruzesterification process for rice farming operations. *OIDA International Journal of Sustainable Development, 8*(12), 25-32. Retrieved from https://ssrn.com/abstract=2730582

Fujita,H., Iijima, W., Nakano, K., Prayitno, J., Tsubaki, H., & Kitagawa, G. (2015). A comparative study of waste cooking oil recycling programs in Bogor and Niigata cities and GHG emission reduction by recycling*. Atlantis Press.* Retrieved from https://www.atlantis-press.com/proceedings/cas-15/22974

Government of Indonesia. (2016). *First Nationally Determined Contribution Republic of Indonesia.* Retrieved from http://www4.unfccc.int/ndcregistry/PublishedDocuments/Indonesia%20First/First%20NDC%20Indonesia_submitted%20to%20UNFCCC%20Set_November%20%202016.pdf

Indonesian Ministry of Health. (2017). *Heart Disease Is the Leading Cause of Death*. Retrieved from http://www.depkes.go.id/article/view/17073100005/penyakit-jantung-penyebab-kematian-tertinggi-kemenkes-ingatkan-cerdik-.html

Kharina, A. & Searle, S. (2016, September 14). Indonesia's delusional strategy for reducing GHG emissions [Blog post]. Retrieved from International Council on Clean Transportation https://www.theicct.org/blogs/staff/indonesia-delusional-ghg-emissions-reduction-strategy

Kruman I, Bruce-Keller AJ, Bredesen D, Waeg G, & Mattson MP. (1997). Evidence that 4-hydroxynonenal mediates oxidative stress-induced neuronal apoptosis. *Journal of Neuroscience, 17*, 5089–5100

Kusuma, H. (2013). Carrefour donates 1,200 used oil to the Bogor Regional Government. *Okezone Finance.* Retrieved from https://economy.okezone.com/read/2013/05/02/320/801288/carrefour-hibahkan-1-200-minyak-jelantah-ke-pemda-bogor

Leong, X.F., Mohd Najib, M.N., Das, S., Mustafa, M.R., & Jaarin, K. (2009). Intake of repeatedly heated palm oil causes elevation in blood pressure with impaired vasorelaxation in rats. *The Tohoku Journal of Experimental Medicine, 219*, 71-78. Retrieved from https://www.jstage.jst.go.jp/article/tjem/219/1/219_1_71/_article/-char/en

Li, H. L. & Yu, P. H. (2015). Conversion of waste cooking oils into environmentally friendly biodiesel. *SpringerPlus, 4*(2), 7. Retrieved from http://doi.org/10.1186/2193-1801-4-S2-P7

Malins, C. (2017). *Waste Not Want Not: Understanding the Greenhouse Gas Implications of Diverting Waste and Residual Materials to Biofuel Production [consultant report]*. Retrieved from The International Council on Clean Transportation https://www.theicct.org/sites/default/files/publications/Waste-not-want-not_Cerulogy-Consultant-Report_August2017_vF.pdf

Mandolesi de Araújo, C. D., de Andrade, C. C., de Souza e Silva, E., & Dupas, F. A. (2013). Biodiesel production from used cooking oil: A review. *Renewable and Sustainable Energy Reviews, 27*(C), 445-452

Petrenko, C., Paltseva, J., & Searle, S. (2016). *Ecological Impacts of Palm Oil Expansion in Indonesia*. Retrieved from International Council on Clean Transportation https://www.theicct.org/sites/default/files/publications/Indonesia-palm-oil-expansion_ICCT_july2016.pdf

Reckerzügl, T. (2013). *Bali: Combating Climate Change and Poverty—Recycling Used Cooking Oil and Transforming it into Biodiesel*. Retrieved from Caritas Switzerland http://www.repic.ch/files/3813/9178/1422/Schlussbericht_Caritas_Indonesia_vf_online.pdf

Soewandi, S. (n.d.). About Us. Retrieved from PT Wahana Abdi Tirtatehnika Sejati http://wats.co.id/about-us.html

Soriguer, F., Rojo-Martínez, G., Dobarganes, M.C., Almeida, J. M. G., Esteva, I., Beltrán, M., De Adana, M.S.R., Tinahones, F., Gómez-Zumaquero, J.M., García-Fuentes, E., & González-Romero, S. (2013). Hypertension is related to the degradation of dietary frying oils. The American Journal of Clinical Nutrition, 78(6), 1092–1097. Retrieved from https://doi.org/10.1093/ajcn/78.6.1092

Srivastava, S., Singh, M., George, J., Bhui, K., Murari Saxena, A., & Shukla, Y. (2010). Genotoxic and carcinogenic risks associated with the dietary consumption of repeatedly heated coconut oil. British Journal of Nutrition, 104(9), 1343-1352. Retrieved from https://doi:10.1017/S0007114510002229

Suriyani, L.D. (2016, September 2). An interesting story of used cooking oil processing into biodiesel in Bali. *Mongabay*. Retrieved from http://www.mongabay.co.id/2016/09/02/cerita-menarik-pengolahan-jelantah-jadi-biodiesel-di-bali/

Thode Filho, S., de Paiva, J.L., Franco, H.A., Perez, D.V., & da Costa Marques, M.R. (2017). Environmental impacts caused by residual vegetable oil in the soil-plant system. *Ciência e Natura, [S.l.], 39*(3), 748-757. Retrieved from https://periodicos.ufsm.br/cienciaenatura/article/view/27645.

Tsoutsos, T. & Stavroula, T. (2013). *Assessment of Best Practices in UCO Processing and Biodiesel Distribution—Guide on UCO Processing and Biodiesel Distribution Methods.* Retrieved from the European Commission https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/d4.3_guide_on_uco_processing_and_biodiesel_distribution_v4tuc.pdf

University of Minnesota. (2005). *Food Fried in Vegetable Oil May Contain Toxic Compound*. Retrieved from Science Daily www.sciencedaily.com/releases/2005/05/050502190054.htm

U.K. Food Safety Agency. (n.d.). *Waste Cooking Oil From Catering Premises*. Retrieved from https://www.food.gov.uk/business-industry/guidancenotes/hygguid/wastecookingoil

U.S. Department of Energy. (2018). *Monthly Biodiesel Production Report.* Retrieved from U.S. Energy Information Administration https://www.eia.gov/biofuels/biodiesel/production/biodiesel.pdf

U.S. Environmental Protection Agency (EPA). (n.d). *Emergency Response, Oil Spills Prevention and Preparedness Regulations-Vegetable Oils and Animal Fats*. Retrieved from http://www.epa.gov/emergency-response/vegetable-oils-and-animal-fats

Valin H., Peters, D., van den Berg, M., Frank, S., Havlik, P., Forsell, N., Hamelinck, C., & Pirker, J. et al. (2015). The land use change impact of biofuels consumed in the EU: quantification of area and greenhouse gas impacts. Retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf

Vanessa, M.C. & Bouta, J.M.F. (2017). Analysis on used cooking oil produced by households in Jabodetabek area. Retrieved from https://www.researchgate.net/profile/Medeline_Vanessa/publication/312755248_ANALISIS_JUMLAH_MINYAK_JELANTAH_YANG_DIHASILKAN_MASYARAKAT_DI_WILAYAH_JABODETABEK/links/58880e9caca272b7b45260b8/ANALISIS-JUMLAH-MINYAK-JELANTAH-YANG-DIHASILKAN-MASYARAKAT-DI-WILAYAH-JABODETABEK.pdf

Venkata, R.P. & Subramanyam, R. (2016). Evaluation of the deleterious health effects of consumption of repeatedly heated vegetable oil. Toxicology Reports, 3, 636-643. Retrieved from https://doi.org/10.1016/j.toxrep.2016.08.003

Wright, T. & Rahmanulloh, A. (2017). *Indonesia Biofuels Annual Report 2017.* USDA Foreign Agricultural Service Global Agricultural Information Network. Retrieved from https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Jakarta_Indonesia_6-20-2017.pdf

Yuniartha, L. (2018). Bulk cooking oil price surpasses IDR 12,500 per liter. *Kontan.co.id*. Retrieved from http://industri.kontan.co.id/news/harga-minyak-goreng-curah-tembus-rp-12500-per-liter

Yuniartha, L. & Laoli, N. (2017). The biodiesel subsidy reaches IDR 5.7 trillion. *Kontan.co.id*. Retrieved from http://industri.kontan.co.id/news/subsidi-biodiesel-hingga-rp-57-triliun

INDONESIA REGULATIONS

New, Renewable Energy, and Energy Conservation (EBTKE) Directorate General Letter No. 1179/12/DJE/2018 regarding market price index of biofuels for March 2018. Signed by Rida Mulyana on February 27th, 2018. Retrieved from http://ebtke.esdm.go.id/post/2018/02/28/1898/harga.indeks.pasar.hip.bahan.bakar.nabati.bbn.bulan.maret.2018

Ministry of Agriculture Regulation No. 11/Permentan/Ot.140/3/2015 Regarding Indonesian Sustainable Palm Oil Certication System /ISPO. Signed by Maran Sulaiman on March 18, 2015.

Ministry of Energy and Mineral Resources Regulation No. 12/2015 Regarding the third amendment of Ministry of Energy and Mineral Resources Regulation No. 32/2008 regarding provision, utilization, and trading of biofuels as other fuels. Signed by Sudirman Said on March 18, 2015.

Ministry of Home Affairs Regulation No. 137/2017 regarding administrative government regions codes and data. Signed by Tjahjo Kumolo on December 27, 2017. Retrieved from http://dukcapil.kemendagri.go.id/peraturan/detail/148/Permendagri-Nomor-137-Tahun-2017-Tentang-Kode-dan-Data-Wilayah-Administrasi-Pemerintahan

Ministry of Energy and Mineral Resources Decree No. 3756 K/10/MEM/2017 regarding the appointment of biodiesel producers and amount of biodiesel procurement for PT Pertamina (Persero) dan PT AKR Corporindo Tbk in November 2017-April 2018 period. Signed by Ignasius Jonan on October 25, 2017. Retrieved from http://ebtke.esdm.go.id/post/2017/10/25/1787/kepmen.esdm.nomor.3756.k10mem2017.tentang.penetapan.badan.usaha.bbn.jenis.biodiesel.dan.alokasi.besaran.volume.untuk.pengadaan.bbn.jenis.biodiesel.periode.november.2017.-.april.2018

APPENDIX A. LIST OF BIOFUEL PRODUCERS

No	Institution	Location	Estimated Capacity (kl/yr)	Source
1	**Yayasan Lengis Hijau**	Denpasar, Bali	600	Suriyani (2016) Reckerzügl (2013)
2	**Wahana Abdi Tirtatehnika Sejati**	Serpong, Banten	3,285	Soewandi (n.d.) Arifenie (2011)
3	**Artha Metro Oil**	Sidoarjo, East Java	N/A	Artha Metro Oil (n.d.)
4	**Genoil / CV. Garuda Energi Nusantara**	Makassar, South Sulawesi	1460	Aria (2016)