Proceedings of the 8th North American International Conference on Industrial Engineering and Operations Management, Houston, Texas, USA, June 13-16, 2023

Drivers and Barriers to Circular Economy in Indonesian Palm Oil

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Abstract

The palm oil industry in Indonesia is one of the largest producers of palm oil in the world, and is an important contributor to the Indonesian economy. However, the industry is facing increasing pressure from environmental and social concerns, such as deforestation, land degradation, and human rights violations. A circular economy offers a potential solution to these issues, as it promotes the efficient use of resources and the reduction of waste. Therefore, this research was conducted to identify the drivers and barriers to the implementation of a circular economy in the palm oil industry in Indonesia. This paper examines the drivers and barriers using CVI and modified kappa method by interviewing a few experts. To achieve this, 32 drivers and 38 barriers were asked to the experts and the results showed that 27 drivers and 3 barriers were valid. The results of the study showed that the most important drivers were the reduction of costs, regulations and government policies, and social pressure. The most important barrier identified was the lack of understanding of the circular economy, lack of economic benefits, and financial constraints. The results of this study provide valuable insights into the factors that need to be addressed to successfully implement a circular economy in the palm oil industry in Indonesia. The findings of this study can be used to inform policymakers and stakeholders of the key drivers and barriers that need to be addressed in order to successfully implement a circular economy in Indonesia's palm oil industry.

Keywords
Circular Economy, Palm Oil, Drivers, and Barriers.

1. Introduction

Palm oil is a versatile commodity that has been widely utilized in various industries worldwide. Palm oil production has increased rapidly in the last 50 years. Based on data from the "Food and Agriculture Organization of the United Nations" (Roser, 2021) in 1970, world palm oil production only reached 2 million tons. The data also shows world palm oil production in 2019 was 35 times higher, reaching 74.58 million tons per year. The rapid rise in palm oil follows a broader increase in demand for vegetable oils. Among the various types of vegetable oil, oil palm is a very productive crop, because it produces 35% of the world's oil, but uses < 9% of agricultural land devoted to oil production.

Palm oil is used in various industries such as food and beverages, cosmetics, personal care products, and household cleaning products. In the food industry, palm oil is widely utilized due to its unique characteristics, such as its high melting point, long shelf life, and neutral taste. Palm oil is used in the production of snacks, baked goods, and frying oils, as it can withstand high temperatures and provides the desired texture and flavor to these products. Furthermore, the demand for palm oil in the cosmetics industry has also grown significantly. Palm oil derivatives such as glycerine, stearic acid, and tocopherol are used in the production of skincare and personal care products. The properties of palm oil derivatives make them useful in moisturizing, emulsifying, and stabilizing cosmetic products, while also providing an extended shelf life.

Indonesia and Malaysia are the dominant players in the global palm oil market, with only a small amount of palm oil being produced in other countries. Indonesia is the largest producer of palm oil globally, accounting for 58% of total global production. Malaysia is the second-largest producer with a market share of 26%, followed by Thailand with 4%, and other countries contributing 12%. Over the past decade, Indonesia has observed an annual increase in palm oil production, with an average growth rate of 6.16%. In comparison to the 2012 production levels, palm oil production

in Indonesia has almost doubled, reaching 20.73 million tonnes. This trend in production is consistent with the increasing trend in global palm oil production observed in recent years (Shahbandeh, 2023).

Palm oil is still one of Indonesia's mainstay commodities in increasing the country's foreign exchange. This is illustrated by its contribution which reached 13.50% to non-oil and gas exports and contributed 3.50% to Indonesia's total GDP. In 2018, palm oil exports reached 34 million tons with a value of around IDR 270 trillion. Export destination countries include India, the European Union, China, Pakistan, Bangladesh, and other countries. (Ditjenbun, 2021). The need for palm oil is projected to continue to increase in the future as stated in the market analysis report. (Grand View Research, 2021; imarc, 2022) projects that the need for palm oil will increase by 4-5% annually. (imarc, 2022)describes the cause of this increase, namely the increasing use in the fields of cosmetics, perfumes, skincare, detergents, shampoos, and conditioners, especially with the increasing variety of emerging online brands. In addition, there has been an increase in the consumption of fried foods due to changes in consumer diets. Coupled with the increasing number of hotels, restaurants, and fast-food chains driving the market growth. The trend of using vegetable oils compared to animal ones also has an influence. Not only that, the use of palm oil as a renewable energy source also has a share, where palm oil can be used to become biomass for power generation and into biodiesel as an alternative to diesel fuel to reduce the accumulation of carbon emissions in diesel engines.

Despite its many benefits, the production and trade of palm oil have raised concerns over environmental issues, especially in sustainability and waste. During harvest, palm bunches and fronds are cut off. In palm oil mills, during the conversion process of fresh fruit bunches (FFB) into crude palm oil (CPO), several kinds of waste including empty fruit bunch (EFB), mesocarp fiber (MF), palm kernel shell (PKS), palm kernel meal (PKM), and palm oil mills effluent (POME) are produced. The production of these wastes is abundant and can be found in 65% of Indonesian oil palm plantation areas. (Hambali & Rivai, 2017) estimate there will be 54 million tons of EFB, 31 million tons of MF, 15 million tons of PKS, 130 million tons of POME, 115 million tons of oil palm frond, and 59.7 million tons the oil palm trunk in 2030. These wastes resulting from the palm oil processing industry still have economic value as they can be used as sources of alternative fuel, fertilizer, chemical compounds, and biomaterials. We need to convert those palm oil waste into something beneficial for the environment and also society, to increase productivity and reduce waste, this system is called Circular Economy.

The implementation of a circular economy (CE) is becoming increasingly imperative across various sectors, including manufacturing, mining, oil and gas, furniture, and fashion (Manoharan et al., 2022; Sharma et al., 2023; Upadhyay et al., 2021; Wicaksono et al., 2022). In contrast to the linear economy (LE) employed in the past, which involved a unidirectional approach to production, the CE is a closed-loop system that embraces the 3R's principle of reduce, reuse, and recycle or even 9R's principle according to (Bappenas, 2021). The LE involved the selection of raw materials, the manufacturing process, and the eventual disposal of waste, which often had significant environmental impacts. The CE, on the other hand, minimizes waste generation by reintegrating waste materials into the production cycle, resulting in less environmental harm. The closed-loop structure of the CE facilitates the conservation of resources by enabling the reuse of waste materials and end-of-life products.

The Indonesian Palm Oil Industry has been reusing solid waste from palm oil for fuel as a substitute for coal since 1980. The use of palm oil waste began to be intensively carried out in 2010 after the Indonesian government enacted a vegetable-based alternative law in 2006, then the use of palm oil waste became more widespread and diversified, including biomass, alternative fuels, and biomaterials. Despite this potential, oil palm companies have not fully utilized these waste products. This research aims to address this gap by exploring the drivers and barriers to implementing a circular economy (CE) in the Indonesian Palm Oil Industry. The research questions are as follows:

1. What are the drivers that facilitate the implementation of CE in the Indonesian Palm Oil Industry?
2. What are the barriers that impede the implementation of CE in the Indonesian Palm Oil Industry?

The present study aims to identify the key drivers and barriers to the implementation of circular economy (CE) in the Indonesian Palm Oil Industry. The study sheds light on the most pressing and relevant factors that can be used by enterprise managers and stakeholders to develop policies and strategies to overcome the challenges that impede CE implementation and promote a successful transition to CE systems. The multifaceted framework developed in this study can serve as a theoretical foundation for future research, particularly in emerging economies.

2. Literature Review

Oil palm is a tropical plant that thrives in areas with high rainfall, abundant sunlight, and humid conditions. Due to these conditions, palm oil is mainly grown in countries located around the equator in Africa, South America, and Southeast Asia. The oil palm fruit grows in dense clusters called Fresh Fruit Bunches (FFB), with each fruit containing multiple palm fruits and having a weight range of 1-25kg.

Ripe palm fruit exhibits a change in colour, from green to a bright reddish orange hue, indicating its ripeness for harvest. Harvesting of Fresh Fruit Bunches (FFB) is carried out by skilled workers who use long-poled knives, also known as dodos, to cut the fruit from the trunk of the oil palm tree. The harvested FFB is then transported by truck to the Palm Kernel Shell (PKS). At the PKS, the FFB undergoes sterilization through steam boiling to facilitate the separation of the palm fruits from the bunches. This process also helps to eliminate enzymes that could potentially lower the quality of the FFB. Once the palm fruits have been detached from the bunches, the empty fruit bunches are separated and used for other purposes. The palm fruit is then processed into two primary products: crude palm oil (CPO) obtained from the mesocarp, and Palm Kernel Oil (PKO) extracted from the kernel of the palm fruit. The mesocarp is pressed to extract CPO, which is then filtered and purified to eliminate contaminants, and subsequently dried in accordance with CPO standard specifications. The oil is then conveyed to a processing plant, where it is transformed into various products, including vegetable oil (such as cooking oil, cream, and margarine), oleochemicals (used in detergents and lubricants), biodiesel (as fuel), and lauric acid (used in cosmetics and soap).

Palm oil plays a significant role in Indonesia's economy by contributing 13.50% to non-oil and gas exports and 3.50% to the country's total GDP. Furthermore, the industry provides employment to over 16 million workers. Additionally, the palm oil sector has facilitated energy independence by replacing fossil fuels through the B20 and B30 biodiesel programs, which produced 9.3 million tons in 2020. The industry has also generated 1,829 MW of electricity from 879 PKS. This has been made possible due to the continuous increase in palm oil production in Indonesia, which is driven by the growing global demand for vegetable oil.
Indonesia, a major producer of palm oil, yields an annual average of 46 million metric tons of the product, thanks to the operations of 2,466 palm oil companies located within the country's borders (Badan Pusat Statistik, 2022). Notably, the largest concentration of these companies is found in five provinces, including North Sumatra (324 companies), Riau (280 companies), West Kalimantan (349 companies), East Kalimantan (318 companies), and Central Kalimantan (203 companies), which collectively account for almost 60% of the total number of companies in operation. However, it is worth noting that not all companies are currently active, as there are currently 346 companies that hold a Temporarily Closed status.

As the global demand for palm oil continues to rise, the amount of palm oil waste generated is also expected to increase (Dwi Januari et al., 2020; Ong et al., 2021). Without proper treatment, this waste can cause significant environmental harm. However, reprocessing of palm oil waste can lead to the creation of value-added products, potentially serving as a new revenue stream for companies. For instance, solid waste can be repurposed for the production of biomass and compost (Rahayu et al., 2018; R. P. Singh et al., 2011), empty fruit bunch (EFB) and Palm Kernel Shell (PKS) can be repurposed as biochar, fertilizer (Anyaoha et al., 2018; Dwi Januari et al., 2020) the mesocarp can be utilized as a valuable component in the production of compost (Anyaoha et al., 2018), while decanter cake can be utilized as ruminant feed (Abdeltawab & Khattab, 2018).

Moreover, palm oil waste presents a promising opportunity to be employed as an alternative material in various industries. Specifically, palm oil waste has been shown to be a viable replacement for fillers in asphalt, a source of sugars for bioethanol production, and a feasible substitute for wood-based industries. Additionally, palm oil waste is a potential biofuel source, with biogas, bioethanol, and biohydrogen being among the most promising options (H'ng et al., 2013; Ong et al., 2021; Rogo et al., 2021; Yacob et al., 2006; Yamada et al., 2010). Some researches (Hafyan et al., 2019; P. Singh et al., 2013) have analysed the utilization of palm oil waste from an economic standpoint. Through the utilization of palm oil waste and the addition of value to it, a Circular Economy is achieved. This model is centred on life extension, product repair, and waste prevention.

Circular economy is "a system solution framework that tackles global challenges" according to (Ellen Macarthur, 2020). By implementing CE means minimize waste and maximize the use of our limited resources by keeping the material in use for as long as possible. Improper usage of materials and energy causes finite resources to become scarcity (Lieder & Rashid, 2016). It helps us to reduce the need of the resources and minimize the impact for environment and society.

The adoption of a CE has become increasingly crucial for industries and enterprises aiming to optimize their production processes while effectively reducing and reusing waste (Bernon et al., 2018). The CE can assist enterprises in improving their economic performance by reducing the cost of excess raw materials, as well as offering significant benefits through proper policy implementation and product management. Researchers and practitioners (Manoharan et al., 2022; Sharma et al., 2023; Upadhyay et al., 2021; Wicaksono et al., 2022) are investigating the various drivers and barriers associated with the implementation of CE in different industries and enterprises.

Numerous palm oil producers in Indonesia have embraced the circular economy approach, exemplified by a company in Riau which converts POME into liquid organic fertilizer and solid waste into chemical fertilizer. Additionally, palm fiber and shells serve as biomass fuel which generates steam for power production (Bappenas, 2021). Another plantation in Kalimantan reported IDR 25 billion (US$ 1.7 million) annual savings from diesel fuel expenses as a result of implementing a circular economy (Lyons, 2019). Pinago Utama minimizes water usage by using recycled water and also implements biogas and biomass (KCSI, 2022). Various other companies also implement circular economy practices.

To facilitate the widespread implementation of the circular economy (CE) within the Indonesian palm oil industry, it is important to gain a comprehensive understanding of the key drivers and barriers that may impact this process. The implementation of CE is increasingly seen as essential across various industries. In fact, many sectors have already begun to identify the key drivers and barriers that may affect the adoption of CE practices. (Agyemang et al., 2019; Khan et al., 2022) have discussed drivers-barriers in automobile industry, (Manoharan et al., 2022) even ranked the driver-barriers using ISM and dematel method. (Gedam et al., 2021; Kumar et al., 2020; Upadhyay et al., 2021) have identified driver-barrier in mining sector and (Sharma et al., 2023) have done the same in oil and gas sector. In agriculture sector, (Rótolo et al., 2022) have explore the barriers in Argentina's agriculture. But there were only a few research have explored circular economy specifically in palm oil industry. (Aliyu Yaro et al., 2022; Bejarano et al., 2022; Lim et al., 2021) have studied about the potential of circular economy from palm oil waste and by products, even the utilization, such as eco-friendly asphalt pavement. (Hwang et al., 2022) proposed CE in palm oil industry to be integrated with other industry that can utilise palm oil waste such as polymer, construction materials, furniture, etc. (Perdana, 2021) analysed the circular economy of used cooking oil but didn't explore the driver-barrier. (Abdul-Hamid et al., 2020, 2021) from Malaysia have done the research for the drivers and the challenge for Malaysian palm oil. In Indonesia, there were a limitation in research for driver barrier circular economy in palm oil industry. This research aimed to explore the drivers and barriers that consist of five categories, financial, market, policy and regulatory, government, and organization.

To achieve the purposed of this research, this study collects the list of the drivers and barriers throughout literature review and compile it into a questionnaire that will be evaluated by the expert. To quantify the expert judgments, several indices have been discussed by (Almanasreh et al., 2019) such as the content validity ratio (CVR), content validity index (CVI), modified–Kappa. This paper used CVI and modified-Kappa method. CVI is one of the most used measures of content validity of an instrument. The experts are asked to rate the relevance of each item on an instrument using a 4-point ordinal scale: "1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, and 4 = highly relevant". Benefits of a 4-point scale include avoiding a neutral midpoint value (Polit & Beck, 2006). Then, for each item, an item-level CVI (I-CVI) is computed by dividing the total number of experts giving a rating of 3 or 4 (relevant) by the total number of experts, I-CVI values should not be less than 0.78.

Although the Content Validity Index (CVI) is commonly used to evaluate content validity in research, it does not account for the possibility of chance agreement leading to inflated values. Thus, (Wynd et al., 2003) recommends utilizing both the Content Validity Index (CVI) and the multi-rate Kappa statistic in content validity studies, as Kappa accounts for chance agreement and provides additional information on agreement beyond chance. A modified Kappa statistic was calculated by first determining the probability of chance agreement for each item through a formula. The evaluation criteria for Kappa were values above 0.74, between 0.60 and 0.74, and between 0.40 and 0.59, which were considered excellent, good, and fair, respectively. (Polit et al., 2007) suggested that, after adjusting for items through calculated adjusted Kappa, items with an I-CVI of 0.78 or higher would be classified as excellent. However, as the number of experts on the panel increases, the likelihood of chance agreement decreases, and I-CVI and Kappa values converge.

3. Methods

This study focuses on examining the factors that facilitate or hinder the implementation of circular economy practices in the Indonesian Palm Oil industry. The drivers and barriers were identified by collecting a list of proposed factors through literature reviews and pre-interviews with practitioners from the industry. The proposed drivers and barriers were presented in Appendix 1 and evaluated by a group of experts consisting of practitioners, academics, and non-government organizations. The experts were selected based on their level of expertise, experience, influence in decisions, and variety of expertise, following the criteria established by (Baker, 2006). The expert panel consisted of five individuals with a minimum of ten years of experience in the field, in line with the recommendations of (Tarei, 2019). The experts assessed the relevance of each driver and barrier to the Indonesian palm oil industry. The results will be evaluated using the modified kappa method.

In order to evaluate the relevance of factors related to the implementation of circular economy in the Indonesian Palm Oil Industry, a questionnaire was developed using the Content Validity Index (CVI) method. The experts were requested to rate each factor's relevance on a 4-point scale ranging from 1 to 4, where 1 indicating irrelevance and 4 indicating very high relevance. The Item-Content Validity Index (I-CVI) value was then calculated for each factor based on the experts' ratings through the formula (1) – formula (3), with a value of at least 0.78 considered to be a valid item (Zamanzadeh et al., 2015). This means that at least 4 out of 5 experts must rate the factor as quite relevant or very relevant. The value of k* was obtained using formula 3.3, and a kappa value above 0.60 was considered good/substantial, indicating that the driver or barrier is relevant. If the kappa value is below 0.60, the factor is considered irrelevant (Almanasreh et al., 2019)

$$Pc = \left[\frac{N!}{A!\,(N-A)!}\right] 0.5^N \quad \text{.... formula 3.1}$$

In this formula 3.1,
Pc = "probability of chance agreement"
N = "number of experts in a panel"
A = "number of panellists who agree that the item is relevant"

$$I-CVI = \frac{number\ of\ experts\ who\ rated\ the\ item\ as\ 3\ or\ 4}{number\ of\ total\ experts} \quad \text{… formula 3.2}$$

$$k* = \frac{I-CVI - Pc}{1 - Pc} \quad \text{… formula 3.3}$$

4. Data Collection

The drivers and barriers were obtained based on the literature review related to circular economy implementation. There are total of 27 driver and 3 barriers are valid after calculated using modified kappa method. The list is shown in Table 1 for drivers and Table 2 for barriers.

Table 1. Drivers Calculation from Expert Validation

No.	Dimen-sions	Drivers	Expert Validation					N	N!	A	A!	Pc	I-CVI	k*	Cate-gory	Result
			A	B	C	D	E									
1	Financial	Production cost reduction	1	1	1	1	1	5	120	5	120	0.03	1	1	Excellent	Valid
2		New potential sales	1	1	1	1	1	5	120	5	120	0.03	1	1	Excellent	Valid
3		Low waste handling costs	1	1	1	0	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
4		Low waste logistics costs	1	1	1	1	1	5	120	5	120	0.03	1	1	Excellent	Valid

5		Price increasing of boiling process fuel	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
6		Increasing production cost due to poor quality	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
7	Market	Sustainability certificates requirement	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
8		Positive branding company	1	1	0	1	0	5	120	3	6	0.31	0.6	0.42	Fair	Invalid
9		The rise of environmental issue	1	1	1	1	1	5	120	5	120	0.03	1	1	Excellent	Valid
10		The existence of the waste management industry	1	1	1	1	1	5	120	5	120	0.03	1	1	Excellent	Valid
11		Diversity of Waste Management Industry	0	1	1	1	0	5	120	3	6	0.31	0.6	0.42	Fair	Invalid
12		Sufficient waste quantity	1	0	0	1	0	5	120	2	2	0.31	0.4	0.13	Poor	Invalid
13	Policy & Regulatory	Integrated legal instruments	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
14		Clear technical regulation	1	1	1	1	1	5	120	5	120	0.03	1	1	Excellent	Valid
15		Supporting tax regulations	1	1	1	1	1	5	120	5	120	0.03	1	1	Excellent	Valid
16		National Action Plan	1	1	1	1	1	5	120	5	120	0.03	1	1	Excellent	Valid
17		Financial support from the government	1	1	1	1	1	5	120	5	120	0.03	1	1	Excellent	Valid
18		Green Industry Standards	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
19		Scoring and levelling system	1	1	1	0	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
20		Privilege from the government	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
21	Organizational	Willingness to improve and get the highest level	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
22		Initial case of CE implementation	1	1	0	1	0	5	120	3	6	0.31	0.6	0.42	Fair	Invalid
23		The presence of inter-company facilitator	1	1	0	1	0	5	120	3	6	0.31	0.6	0.42	Fair	Invalid
24		CE implementation policy	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
25		CE supporting activities	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid

26		Environmental Management System	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
27		Integration with CSR program	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
28	Operati-onal	Good infrastructure	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
29		CO2 emission reduction	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
30		The impact of on environ-mental safety	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
31		Less energy consumption	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid
32		Good waste treatment technology	1	1	0	1	1	5	120	4	24	0.16	0.8	0.76	Excellent	Valid

Table 2. Barriers Calculation from Expert Validation

No.	Dimen-sions	Barriers	Expert Validation					N	N!	A	A!	Pc	I-CVI	k*	Category	Result
			A	B	C	D	E									
1	Financial	Lack of economic analysis method	1	0	0	1	0	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
2		Lack of economic benefits	1	1	0	1	1	5	120	4	24	0.16	0.80	0.76	Excellent	Valid
3		Low selling price of yield	1	0	0	1	0	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
4		High upfront investment cost	1	0	0	1	1	5	120	3	6	0.31	0.60	0.42	Fair	Invalid
5		Limited funding for CE models	1	0	0	1	0	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
6		Lack of government subsidies	1	0	0	1	0	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
7	Market	Lack of market availability	1	0	0	0	1	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
8		Lack of consumer awareness	1	0	0	1	0	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
9		Lack of awareness of residents around factory	1	0	0	1	1	5	120	3	6	0.31	0.60	0.42	Fair	Invalid
10		Lack of SME role	1	0	0	1	1	5	120	3	6	0.31	0.60	0.42	Fair	Invalid
11		Lack of marketing activities	1	0	0	1	0	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
12		Lack of awareness in society	1	0	0	1	1	5	120	3	6	0.31	0.60	0.42	Fair	Invalid
13		Lack of competent labour	0	0	0	1	0	5	120	1	1	0.16	0.20	0.05	Poor	Invalid
14	Policy & Regulator y	Lack of government reporting system	0	0	0	0	0	5	120	0	1	0.03	0.00	-0.03	Poor	Invalid
15		Lack of waste management regulations	0	0	0	1	1	5	120	2	2	0.31	0.40	0.13	Poor	Invalid

16		Lack of regional regulations	0	0	0	1	1	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
17		Customization of regional regulations	0	0	0	1	0	5	120	1	1	0.16	0.20	0.05	Poor	Invalid
18		Lack of coordination from the central government to the regional government	0	0	0	1	1	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
19		Lack of compliance supervision	0	0	0	1	1	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
20		Lack of law enforcement related to environmental	0	0	0	1	1	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
21		Lack of promotion to industry	0	1	0	1	1	5	120	3	6	0.31	0.60	0.42	Fair	Invalid
22	Organiza-tional	Lack of understanding related to the economic potential of the CE	0	1	0	1	1	5	120	3	6	0.31	0.60	0.42	Fair	Invalid
23		Lack of awareness for waste management	0	1	0	1	1	5	120	3	6	0.31	0.60	0.42	Fair	Invalid
24		Lack of waste utilization planning	0	0	0	0	0	5	120	0	1	0.03	0.00	-0.03	Poor	Invalid
25		Lack of top management support’	0	1	0	1	1	5	120	3	6	0.31	0.60	0.42	Fair	Invalid
26		Lack of company initiative	0	1	0	0	1	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
27		Outside of the core business	0	0	0	1	0	5	120	1	1	0.16	0.20	0.05	Poor	Invalid
28		Impediment in using new technology	1	0	0	1	0	5	120	2	2	0.31	0.40	0.13	Poor	Invalid
29		Limited funds for R&D	1	0	0	1	1	5	120	3	6	0.31	0.60	0.42	Fair	Invalid
30		Lack of training	1	1	0	1	1	5	120	4	24	0.16	0.80	0.76	Excellent	Valid
31		Lack of integration within the company	1	1	0	1	1	5	120	4	24	0.16	0.80	0.76	Excellent	Valid
32	Operatio-nal	Variance of POME quality	1	0	0	0	0	5	120	1	1	0.16	0.20	0.05	Poor	Invalid
33		Limitation of waste treatment technology	1	0	0	1	0	6	720	2	2	0.23	0.33	0.13	Poor	Invalid
34		The technical complexity of waste treatment	1	0	0	1	0	7	5040	2	2	0.16	0.29	0.15	Poor	Invalid
35		Intense maintenance process	0	0	0	1	0	8	40320	1	1	0.03	0.13	0.10	Poor	Invalid

36		Need to analyze groundwater and surface water'	0	0	0	1	0	9	362 880	1	1	0.02	0.11	0.10	Poor	Invalid
37		WWTP leakage due to topography	0	0	0	1	0	10	362 880 0	1	1	0.01	0.10	0.09	Poor	Invalid
38		Lack of measurement of CE performance	0	0	0	1	0	5	120	1	1	0.16	0.20	0.05	Poor	Invalid

5. Results and Discussion

In this section, the result of (k*) value of the drivers and barriers are discussed in the perspective of the literature and research objectives from the experts.

5.1 The Drivers

There are 32 drivers that were selected in this study, they were categorized in 5 dimensi, financial, market, policy and regulatory, organization, and operational. From 32 drivers, there were 27 of them were valid.

On financial category, there were 6 drivers, all of them are valid. There were 3 items that approved by all of the experts. They were reduction of production costs, new sales potential, and low transportation costs. It's interesting that there 1 expert says low handling costs is not really relevant because some companies give the palm oil waste freely to the waste management company (third company) and it can't boost the implementation of circular economy, because the transportation cost is relatively high. All of the experts agree if the transportation cost is low, it will facilitate the palm oil factory to utilize the waste. (Gregor et al., 2017; Hermawan, 2018) have done the research to optimize the transportation of waste from source to the treatment facility using techno-economic method. Although various studies have explored this topic, it is not highly pertinent to the current state of the Indonesian palm oil industry. The distance between factories is substantial, with each factory occupying approximately 100 hectares. Subsidizing logistics costs by the government could benefit both the palm oil companies and treatment facilitators. Alternatively, the government could assist in mapping the treatment facilitators' locations in each palm oil mill area, ensuring that they receive sufficient waste quantities while balancing logistical expenses. The palm oil companies could also take the initiative of employing their vehicles to facilitate waste distribution to treatment facilities. In the event of an increase in boiler fuel prices, such as coal, factories may utilize solid waste as an alternative fuel source. Biochar could even replace coal in boiler processing in situations where coal prices soar. A government-regulated minimum price for coal could revolutionize boiler fuel usage in the palm oil industry.

On market category, from 6 drivers, there were 3 that are valid. The requirements for sustainability certificates such as "Roundtable on Sustainable Palm Oil" (RSPO), "Indonesia Sustainable Palm Oil (ISPO), "International Sustainability and Carbon Certification" (ISCC) from consumers forced oil palm producers to implement circular economy. It is aligned with the other item the increasing the issue of sustainability/circular economy in the community that also valid. The implementation of a certification or labelling system for products that adhere to circular economy (CE) principles presents an opportunity to raise consumer awareness and incentivize companies to adopt CE practices. By rewarding leading companies with a "green premium," this system could also accelerate the adoption of CE principles. However, a major hurdle in implementing such a system is the need for consistent and standardized methodologies across different countries (Preston, 2012). The rise of environmental issues in the community will encourage companies to implement the circular economy. As public awareness of sustainability issue continues to grow, consumers are becoming more environmentally conscious and are demanding more sustainable products and practices from companies. (Esty & Winston, 2006) have shared how several companies did smart movement towards environmental issue to create value and build competitive advantage. Other item that valid is the existence of third company that focus on waste management or as waste treatment facilitator, because waste processing is sometimes outside of the company's core business. The existence of this company can help palm oil produsen to manage the waste. 3 items that are not valid are Branding Company, Diversity of Waste Management Industry, and the presence of several companies that can provide sufficient waste quantity to be utilized by third company. The experts claimed that the company didn't need to branding themselves as circular economy company. The implementation of the Circular Economy (CE) concept is deemed to enhance a positive corporate image, although it is not currently considered a significant driver in the industry. Consumers prioritize pricing above all other considerations, rendering cost-cutting and fast sales strategies as the primary focus of corporations. Despite the endorsement of three out of five

experts, the waste management sector's variability is deemed largely irrelevant. Competition within the waste management industry can promote companies to offer competitive prices for waste treatment, although certain Indonesian companies overlook this aspect as they do not suffer any losses. The presence of several companies capable of supplying a significant waste volume for third-party companies' utilization is considered insignificant. Palm oil companies typically possess large land areas, and their geographical locations are often distant from one another. This situation results in third-party logistics costs presenting a significant challenge for such companies.

On policy and regulatory category, there are 8 items of drivers and all of them are valid. Integrated Legal Instruments, such as Circular Economic Law Umbrellas such as Basicreclaw (Japan), Integrated Product Policy Directive (European Union), and Circular Economy Promotion Law (China) is one of the main needs in Indonesian Palm Oil industry. These integrated legal instruments help to minimize the waste by looking at all phases of a products' life-cycle and taking action where it is most effective. It will be a guidance to all palm oil companies to create a greener supply side, and the demand side will also be educated. “Green Industry Standards” movement from government also can boost the implementation of circular economy, because the practitioner, the academic, and other roles discussed the standards to achieve best scenario to implement circular economy that suits with Indonesian palm oil industry. This movement will increase the pressure between the palm oil company to follow and implement the standards. But both of legal instrument or Green Industry Standards need to provide a clear and detailed technical regulation from central government to local government. It needs comprehensive socialization and strict supervision from the central government so that all parties involved have the same frequency.

Reward and award will be a booster for palm oil companies to implement circular economy. The recycling of various materials is often deemed uneconomical compared to the production of new materials, which impedes the implementation of recycling programs. However, if there are incentives in place to encourage strategic planning from the product design stage to the consumer, the economic feasibility of recovery and reuse could be significantly improved (Preston, 2012). Pricing in the externalities associated with resources and encouragement of minimal resource use, waste and pollution. Government can give an incentive or subsidies as the reward for palm oil company that put the materials back into circulation. It can be in the form of land-value taxes or value-extracted taxes. Award certification or label for the company that implemented resource efficiency or a circular economy need to promote to society so the consumers will understand and value the product itself. This kind of award such PROPER that have been implemented in Indonesia need to have an interesting benefit each level, so the company can continue to raise their level to the highest level.

On organizational category, there are 5 out of 7 drivers that were rate as relevance factors. They were ‘the willingness of the company to get the highest level of award likes PROPER level’, if the company aimed to get the highest level of award, such as PROPER, it will be a company culture. The entire company will design the process towards CE. This will lead to other barriers ‘the strategic policies to implement CE within the company’ and ‘there are supporting activities for circular economy practice’. If the company have a strategic planning and policy such as add CE as one of the KPI, it will push each of department to redesign their process from linear system into circular system. It will drive the implementation of CE within the company. Companies can give a reward to employee or department that successfully implement CE in their process. The company needs to review the process on a certain period; hence the team will always come up with a new idea about how to utilize the waste in their department.

The fulfillment of an ‘Environmental Management System such as ISO 140001’ can drive the implementation of CE practices because involves setting environmental goals and objectives, identifying and controlling environmental risks, and continuously monitoring and improving environmental performance. By implementing an EMS, companies in the palm oil industry can identify opportunities to improve their environmental performance, identify areas of waste and inefficiency in their production processes and develop strategies to reduce waste, maximize the use of resources, and improve their overall environmental sustainability. Besides, it also helps to comply with regulations, and meet stakeholder expectations for environmental sustainability.

In the view of increased energy demand, environmental issue and carbon emissions, the company can collaborate with society around the factory to manage the palm oil waste through Community Development Program. By integrating Corporate Social Responsibility program with CE implementation, it will facilitate the implementation of CE in Indonesian palm oil industry because the company can achieve a few targets once in a program.

There are two items from organizational category that weren't valid, they were the 'initial CE implementation case' and 'existence of facilitators within the company'. Companies tend to follow other companies that have been proven successful in implementing CE. In Indonesian palm oil industry, it's not relevant because the company need to implement CE as soon as possible because it's the requirement from their customers. They can't sell their product to some customers if they didn't fulfill it. The presence of intercompany facilitator can increase the awareness of CE implementation across the palm oil company but they didn't have a big power to pushed the company to implement CE.

On operational category, there were 5 items on the list and all of them are rate as quite relevant to be the drivers to implement circular economy in Indonesian palm oil industry. 'Good connecting infrastructure' will be the main driver in this category, because great infrastructure such as roads, trains, ports, or airports near industrial areas that integrate one another will facilitate waste logistics. 'Low emission boiler fuel' assessed as the driver of CE implementation. Solid waste from palm oil can be used as alternative fuel for boiler process and it has a lower emission CO2 than fossil fuel or coal. It drives company to utilize solid waste from palm tree and palm fruit to substitute fossil fuel and coal for boiler process. While it achieves CE implementation, it also reduces CO2 emotions at the same time. 'The impact of waste on environmental safety' that is not treated/processed improperly can cause environmental risks such as water pollution, soil fertility, and can cause health problem. This issue needs to promote thus the society become more aware and can help government to keep an eye on palm oil companies to treat their waste properly. The existence of 'waste treatment technology' that more effective for managing palm oil waste, especially POME, will make it easier for companies to manage their waste.

5.2 The Barriers

There are 38 items that were selected in this study that have the potential to become the barrier that can impede the implementation of circular economy in Indonesian Palm Oil Industry. Same with the drivers, they were categorized in 5 dimensi, financial, market, policy and regulatory, organization, and operational. Unlike the drivers that most of the drivers were valid, in this barrier section most of the items were not valid. There were only 3 barriers are valid, while another 35 items are not valid. This happen because most of the experts said that Indonesian palm oil industry need more drivers, there were not barriers that really impede the implementation of circular economy. It's just need to be pushed in some ways.

On the financial category, there were six items of barriers have been proposed to the experts. Only one items there were valid, it is the 'lack of economic benefits. The content and amount of waste currently is still not economical with the investment costs, the effort, and might need a little bit time to get a break-even-point. It may cause by the low value of the product from the waste treatment. Governance needs to create a scenario or collaboration with local small-medium enterprise to create a product with high economic value.

There were 3 out of 5 experts agree that the cost of technology investment at the beginning might be a barrier to the company to treat the waste. 'High upfront investment costs' might be a barrier for a small to medium company, but not for a big company. Some companies might be waiting for the success of companies that have implemented CE, whether it bring big revenue or not. Other items, 'lack of economic analysis methods' is not relevant because many companies already have the calculation for investment and operation of circular economy activities, also may research have done techno-economic about waste utilization. 'Low FFB material prices' also not relevant because
the price of FFB usually dynamic. The low selling price of FFB can reduce the spirit to implement the circular economy. 'Limited funding for CE models' and 'lack of government subsidies' also not relevant as the barriers to implement CE in Indonesian palm oil industry.

On the market category, there were 7 items of barriers and all of them are not valid as the barriers. Most of the experts were agree that 'Lack of awareness of residents around the factory' and 'Lack of Role of SME' are the barriers in CE implementation. (Pramata, 2021) said many companies discharge POME into the river, but the resident around the river didn't aware of the dangers of the contamination, so they never give the pressure to the company. It also happened with the 'lack of SME's role'. SME that managed palm oil waste are very limited, the factory also didn't collaborate with the society near the factory to integrate their Community Development Program to educated how to manage the waste and turn it into a product that has economic value.

'Lack of marketing activities' and 'lack of CE issue' in society might be a symptom of barrier 'Lack of consumer awareness' that led to 'Lack of market availability'. The campaign of CE in society, rather from company, government,

and media not massive. Hence, the society less aware of the importance of CE implementation. The consumers then put price as the first priority. 'Lack of competent labor' that has skills relate to CE also not relevant because there are many employees that understand and have the skill about CE.

On the policy and regulatory category, there were invalid 8 barriers. 'Lack of Government Reporting System' is not relevant because the industrial waste reporting system to the government is considered good and has even been digitized. This certainly makes it easier for the company. 'Lack of waste management regulations', 'lack of regional regulations', 'Customization of Regional Regulations', 'lack of coordination from the central government to the regional government', 'lack of law enforcement related to environmental' and 'lack of compliance supervision' also not considered as the valid barrier. The practitioner said they have implemented CE in their company not because lack of regulation from government but because they to maintain their certification and fulfill some requirements regarding CE to have the chance for import. But the expert agreed that if the government released a policy regarding CE and strictly monitor its implementation, accompanied by punishments and rewards, then it will encourage a wider implementation of CE to all level companies, from small, medium, and large enterprise. Lack of compliance supervision. Last barrier from this category was 'lack of promotion to industry' from government. The government has promoted yet the circular economy, but not every company have the attention to implement it.

On the organization category, there were ten items that proposed to be the barrier for CE implementation in palm oil industry. Only 2 barriers are valid, but there are 4 barriers that have a fair kappa value, and other 4 barriers are invalid. 'Lack of training' to understand the concept of circular economy from top management to employees might impede the CE implementation. By conducting a training, the employee can understand CE model properly, but it may require a huge money to have a proper training. Human Resources team should comprehend that having the appropriate abilities/skills would allow companies to create products that adhere to circular practices. This may be a significant obstacle to the successful adoption and execution of a CE. 'Lack of integration within the company' are also valid as barrier. Implementation of CE need a collaboration from all stakeholders in company. All of managers and them team within and across department needs to work collectively.

There are 4 barrier that have a fair kappa value, they were 'lack of knowledge related to the economic potential of the CE', 'lack of awareness for waste management', 'lack of top management support', and 'limited funds for R&D'. Some of the experts agree they might be barriers because the understanding of the content, amount, value and potential for the waste utilization within the company is limited even minimal. Without support and participation from top management, it is complex to implement any innovation process or technology.

There are 4 invalid barriers in this research. 'Lack of company initiative' and 'lack of waste utilization planning' it might be a barrier because the implementation of CE will require effective planning and management, for the designing scenarios to minimize waste and maximize the resources. But this not valid because many companies already have a comprehensive plan to implement CE. Some companies may can't implement CE in the process because it's 'outside of the core businesses. It may require a new department, a new team. But in Indonesian palm oil industry, this is not relevant because even CE activity is beyond the primary focus of the company's operations, the company can collaborate with the third company to manage the waste. The barrier 'impediment in using new technology' is also invalid. Highly developed technology and updating equipment and facilities provides a way to accomplish CE, but it might hard for some employee to adapt with the new system or technology. But it can't impede the implementation of CE.

On the operational category, there were 7 invalid barriers. 'Variance of POME quality', 'intense maintenance process', 'need to analyze groundwater and surface water', 'WWTP leakage due to topography', 'lack of measurement of CE performance', 'limitation of waste treatment technology', and 'the technical complexity of waste treatment'. This is simply because it did not occur in every factory, and it is not considered a hindrance since the adoption of CE in the palm oil industry persists regardless of whether this occurs or not.

6. Conclusion

The CE concept is gaining momentum these days as an allegedly novel pathway towards sustainable development. Numerous regions and countries have committed to implement CE in many sectors, start with the prioritize sectors each country. Despite palm oil is not the top 5 sector prioritized to implement CE in Indonesia, palm oil industry needs to prepare and implement CE in the process.

The study identifies and offers an understanding of the relevant CE drivers and barriers implementation in Indonesian palm oil industry that can be a foundation to design effective management strategies and policies for the transition of

linear model product flow to circular systems. We find that palm oil industry needs drivers to implement CE, because many of the possible barriers haven't relevant. The possible barriers happened in the industry and might impede the CE implementation but it's not difficult to deal with it. Indonesian palm oil industry needs more external pressure to have a massive movement towards CE implementation. Currently, only several companies implement CE in the process due to the requirements from their customers, especially those outside Indonesia.
The study reveals that the industry is primarily driven by the potential benefits of CE, such as increased profits, new revenue sources, market share, and enhanced shareholder benefits, as well as cost reduction. This finding is in line with previous research on CE implementation. Additionally, strong policy and regulatory support from the government is essential to provide integrated legal instruments and CE standards that guide all industry stakeholders. These regulations and standards should include penalties and rewards to encourage the industry to adopt CE initiatives. Furthermore, enterprises' environmental concerns, such as designing for the environment, resource efficiency, reduced CO2 emissions, and a focus on sustainable business growth, also drive managers to consider CE implementation.

On the other hand, due to the fact that there is a lack of integration within the company, it's indicated that many departments are might not aware or well informed on the idea of CE. It might be caused by the limitation of funding to conduct a training to the employee. Human Resources team should comprehend that having the appropriate abilities/skills would allow companies to create products that adhere to circular practices. Implementation of CE need a collaboration from all stakeholders in company. All of managers and the team within and across department needs to work collectively.

The barriers that also impede CE implementation is big upfront investment. The financial cost of investment needed for CE implementation made many enterprises are hindered to implement CE initiatives. Some companies, especially small-medium companies, might be waiting for the success of companies that have implemented CE, whether it bring big revenue or not.

The study reveals that the drivers and barriers of Circular Economy (CE) predominantly originate from external factors rather than internal ones. Overcoming these impediments to CE initiatives necessitates the government's proactive role in maintaining CE's momentum. To this end, the government must implement environmentally-friendly policies that promote CE awareness within society while establishing regulations and incentives that encourage companies to adopt circular processes. Despite the challenges, the increasing acceptance of the CE concept by sustainable development practitioners offers hope for experimentation and identification of successful CE business models that achieve mainstream adoption, ultimately ensuring CE implementation success.

Admittedly, this study has several limitations. The scale of palm oil companies in Indonesia consists of small companies to MNC companies. This of course can make the results of this study not fully related. Even though, we have presented the experts from small company to multi-national company, the non-government organization, and the academics. Furthermore, our study initiates to identify the drivers and barriers in Indonesian Palm Oil Industry. These limitations represent various viable avenues for future research on this topic. The future work may attempt to expand the experts. Also, this research suggests to use DEMATEL, AHP, ANP, etc. to evaluate the identified drivers and barriers. It will determine the priority order of drivers and barriers and relationships between the drivers and barriers.

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Appendix

The Drivers

No.	Dimensions	Drivers	Description
1	Financial	Production cost reduction	Resource cost that needs for production, such as energy, raw materials, water, etc. can reduce
2		New potential sales	The utilization of oil palm waste into more useful products can be a new revenue stream for the company
3		Low waste handling costs	The cost of waste treatment from third parties decreases
4		Low waste logistics costs	Low logistics cost can decrease waste treatment pricing and help the company to deliver the waste
5		Price increasing of boiling process fuel	High price of boiler fuels such coal and fossil fuel, can increase the utilization of solid waste as the alternative fuel in boiling process
6		Increasing production cost due to poor quality	Production costs will increase due to a decrease in the quality of raw materials, it will boost palm tree rejuvenation
7	Market	Sustainability certificates requirement	The requirements for RSPO/ISPO/ISCC certificates from consumers forced oil palm producers to implement CE in production process
8		Positive branding company	The implementation of the circular economy provides a positive image for the company, improve company reputation and brand value, as well as attract environmentally conscious customers and investors.
9		The rise of environmental issue	Massiveness environmental issues in the society will push companies to implement CE and produce a greener product with a circularity process
10		The existence of the waste management industry	The existence of companies that focus on waste management or waste treatment will help producer to manage their waste
11		Diversity of Waste Management Industry	The variance of third company as certified waste processing companies will create a competitive environment in offering pricing and quality
12		Sufficient waste quantity	The presence of several companies capable of supplying a significant waste volume as the input process for third-party companies
13	Policy & Regulatory	Integrated legal instruments	Comprehensive and integrated Circular Economic Law, such as Basicreclaw (Japan), Integrated Product Policy Directive (European Union), and Circular Economy Promotion Law (China)
14		Clear technical regulation	There are technical regulations detailing the general rules of how to implement a circular economy
15		Supporting tax regulations	Taxes will encourage industry players to implement CE activities and increase government budgets to encourage the implementation of related practices
16		National Action Plan	National Action Plan that contains National Target of CE for palm oil companies and the programs/activity achieve it
17		Financial support from the government	There is specific financial support such as state equity participation, subsidies
18		Green Industry Standards	A standard to create a Green Palm Oil Industry Standardization as a guideline for CE implementation
19		Scoring and levelling system	Award from government that consist of a few levels, each of it has different value of reward to encourage companies to continue develop CE implementation

20		Privilege from the government	The government gives privilege as reward for companies that have implement CE in a certain criterion
21	Organizational	Willingness to improve and get the highest level	The willingness to improve and get the highest level of sustainability drives the company to set specific goals and objectives, great will will push the whole company to improve towards CE
22		Initial case of CE implementation	Companies tend to follow other companies that have been proven successful in implementing something like CE, initial case of a company that has multi-benefit by implementing CE will encourage other company to follow it
23		The presence of intercompany facilitator	The presence of intercompany facilitator, such as association can increase the awareness of CE implementation across the palm oil company
24		CE implementation policy	By adopting a CE policy, companies can set specific goals and objectives for implementing circular economy practices in their production processes, supply chain, and business operations
25		CE supporting activities	Through CE activities, companies can demonstrate their commitment to sustainability and environmental responsibility
26		Environmental Management System	Fulfilment of Environmental Standards/Regulations such as ISO 140001 will increase the awareness of company about sustainability/CE, because EMS approach to managing an organization's environmental impact and improving its environmental performance.
27		Integration with CSR program	CE practice has the potential to be integrated in the implementation of the company's CSR program, it will help to increase the awareness of society about CE
28	Operational	Good infrastructure	The existence of infrastructure such as toll roads, trains, ports, or airports near industry/industrial estates to facilitate waste logistics
29		CO2 emission reduction	Coir and shell as boiler fuel have lower carbon emissions than other fuels such as coal
30		The impact on environmental safety	Oil palm waste that is improperly managed poses a serious threat to human health and the environment, such as water pollution, soil fertility, etc.
31		Less energy consumption	The circular economy can help reduce energy consumption which then reduces the production of CO2 emissions
32		Good waste treatment technology	The existence wastewater treatment plant technology that is more effective and efficient in managing waste, especially POME makes it easier for companies to manage waste

The Barriers

No.	Dimensions	Barriers	Description
1	Financial	Lack of economic analysis method	Companies/organizations do not have economic calculation methods for investment and operation of CE activities
2		Lack of economic benefits	The content and amount of waste currently is still not economic beneficial with high investment costs and long-time BEP
3		Low selling price of yield	The low selling price of FFB can reduce the motivation and focus on waste management, if it were higher there would be more affordable CE products that could spur consumer interest and awareness
4		High upfront investment cost	Investment of waste treatment technology requires a high upfront cost
5		Limited funding for CE models	Investment is needed for transition to the circular economy. However, debtors such as banks are still unable to channel a lot of investment because of uncertainty in risk calculation
6		Lack of government subsidies	Lack of incentive from the government for investment in waste treatment technology

7	Market	Lack of market availability	There are still consumers who do not require RSPO/ISPO/ISCC certificates in their purchases, only focusing on prices.
8		Lack of consumer awareness	Consumers are less aware of the importance of the application of the CE and a sustainable system in the palm oil industry
9		Lack of awareness of residents around factory	The community is less aware of the dangers of oil palm waste that is around it so that the supervision of waste management is minimal.
10		Lack of SME role	There is no MSME that manages oil palm waste so that the community is also less interested in utilizing waste
11		Lack of marketing activities	Lack of marketing activities of company related to circular economy
12		Lack of awareness in society	Lack of CE issues in the community so that the company is not prioritize CE implementation to build the company's branding
13		Lack of competent labour	Lack of competent labour and has skills related to the circular economy
14	Policy & Regulatory	Lack of government reporting system	Waste reporting from the industry is not good because there is no obligation or government -owned reporting information system
15		Lack of waste management regulations	Regulations related to the processing of oil palm waste from the central government are not clear and specific.
16		Lack of regional regulations	Regional government do not require all palm oil industry players to utilize waste production.
17		Customization of regional regulations	Each local government can make their respective policies related to the processing of oil palm waste from National Regulation and customised it based on local condition
18		Lack of coordination from the central government to the regional government	Lack of coordination of the central government regarding procedures and contents of regional regulations related to processing oil palm waste
19		Lack of compliance supervision	Mechanisms to ensure companies comply with government regulations are unclear or do not yet exist
20		Lack of law enforcement related to environmental	The implementation and transparency of enforcing rules against environmental polluters has not gone well
21		Lack of promotion to industry	The government has not massively promoted the circular economy so not all industry players understand its benefits
22	Organizational	Lack of understanding related to the economic potential of the CE	Lack of understanding regarding the content, amount, and potential benefits of waste utilization
23		Lack of awareness for waste management	The company doesn't care about waste treatment and its bad impact on the environment.
24		Lack of waste utilization planning	The company does not plan waste management according to government regulation.
25		Lack of top management support’	There is no support from top management
26		Lack of company initiative	Initiative from companies in implementing CE is still low
27		Outside of the core business	CE activities are outside the company's core business

28		Impediment in using new technology	The adoption of new technology is difficult and complex as it requires rigorous testing and assessment to justify large investments
29		Limited funds for R&D	Limited allocation of research and research costs in companies related to the circular economy
30		Lack of training	Limited training or workshop to understand CE concepts for the employees
31		Lack of integration within the company	Strong integration of company functions facilitates the implementation of green innovation. The lack of integration between company functions makes it difficult to implement a circular economy
32	Operational	Variance of POME quality	Palm liquid waste from each factory has different characteristics, each company must research it first.
33		Limitation of waste treatment technology	Waste utilization technology is still limited and its development has not been significant
34		The technical complexity of waste treatment	Waste processing techniques require detailed planning and execution so that supervision must also be detailed to minimize the impact that occurs.
35		Intense maintenance process	It is necessary to periodically check the waste area to avoid siltation of the pond
36		Need to analyze groundwater and surface water'	Periodic analysis is needed to detect WWTP and flatbed leaks
37		WWTP leakage due to topography	Aerobic and anaerobic pond systems have the opportunity to experience bottom leakage of sewage ponds due to porosity in the soil that was not identified from the start
38		Lack of measurement of CE performance	Performance measurements for circular economic activities are lacking or not available so that circular economic activities are not measurable even though they have started to exist

Biographies

Dr. rer.pol Romadhani Ardi S.T., M.T is an Assistant Professor at Universitas Indonesia, in Depok, Indonesia. He teaches at the graduate and undergraduate level, with almost 14 years of experience. He graduated as an Industrial Engineer from Universitas Indonesia in 2009 and continue his Master's Degree in the same field while becoming a Lecturer Assistant at 2009-2011 then became a Lecturer at 2011. He continued to study at University of Duisburg-Essen at 2013 and got the Doctor rerum politicarum degree in 2016. Currently he got promoted as Associate Dean for Student Affairs, Research and Community Engagement at Faculty of Engineering Universitas Indonesia. His expertise is in the fields of environmental engineering and sustainability, especially circular economy and e-waste management. He trained in systems analysis on e-waste management as well as in advanced statistical analysis. His research focuses in the development of sustainable waste management systems, the use of renewable energy sources, and the development of sustainable communities. He has published numerous papers on these topics and has presented his work at international conferences. He is also experienced in working on building community engagement projects of sustainability issues. He has a deep understanding of the complexities of sustainability issues and the importance of engaging communities in the process.

Widyaningsih Sura is a graduate degree student in Industrial Engineering, Universitas Indonesia. She got her bachelor degree as Metallurgy and Materials Engineer in 2018 also in Universitas Indonesia. She has published a paper about Metakaolin from Bangka Indonesia as Additive in OPC and got a patent from that research. She works at trading materials company that pushed her to have a deep understanding about supply chain and sustainability.