Life cycle cost (LCC) and the economic impact of the national biofuels development through biorefinery concept and circular economy

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Abstract. The challenge in the life cycle costing (LCC) analysis of the national biofuel industry is an economic analysis to determine all production costs incurred by the production process from facility construction to waste management. Regarding the Biofuel Supply Chain, the entire process of producing palm oil biodiesel is divided into three stages: production of fresh fruit bunches (FFB), production of crude palm oil (CPO), and biodiesel. LCC analysis is applied by adding an externality variable, providing comprehensive information on the cost structure of palm oil-based biodiesel production. To determine the total cost of externalities that occur due to biodiesel production, the impacts of land use, social costs and environmental costs such as emissions of air pollutants on palm oil biodiesel are considered. The results show that the LCC analysis applied by adding externality variables provides detailed information about biofuel production costs' composition and hotspots. It can be used to determine hotspots, streamline production, obtain an overview of the most competitive total production costs, and minimize environmental impacts along its supply chain.

1. Introduction
At the macro level, the mandatory biofuels policy has a positive impact on strengthening national energy security and healthier state finances. Based on the potential generated by biofuels, ranging from saving foreign exchange glass, mitigating greenhouse gases (GHG) and increasing the workforce in the palm oil sector, this program is feasible to be continuously improved and developed in Indonesia [1, 2].

Since January 1, 2020, the Indonesian government has implemented the mandatory B30 program, namely the obligation to mix biodiesel as much as 30% of the total diesel fuel. Indonesia has high productivity of palm oil for biodiesel production [3]. Figure 1 shows a graph of Indonesia's 2015-2019 balance of palm oil production and consumption. Indonesian palm oil production continues to increase from year to year. The B30 program can increase domestic palm oil uptake [4].
The development of palm oil-based bioenergy, especially biodiesel, can positively impact the Indonesian economy [5]. The weakness of biodiesel is the high production cost. This causes a significant price difference between biodiesel and fossil diesel. However, biodiesel production produces a by-product in the form of glycerol which has economic potential. The increase in biodiesel production will increase the by-product in the form of crude glycerol [6]. Glycerol can be used as a raw material for propellants, which imports have fulfilled. This supports the government’s efforts in developing industrial propellants to increase the independence of the defense industry [4].

However, in the biofuel supply chain, there are a number of challenges such as how to assess the economic impact of circular Economy, overall supply chain in the upstream sector, ranging from land preparation, plantation, processing unit (biorefinery), utilization of waste until the downstream energy plantation products [7]. Implementing the biorefinery concept and circular economy is essential in developing national biofuels, namely by implementing it in an integrated manner. Figure 2 illustrates an integrated palm oil-based energy plantation scheme. This system integrates agricultural waste management to ensure optimal utilization of biological resources as well as environmental sustainability for existing oil palm plantations [8]. The impact, both in terms of economic and environmental aspects, is certainly very positive, including in this case can reduce effluent waste or even become zero waste.

**Figure 1.** Balance chart of production and consumption of Indonesian Palm oil 2015-2019 [4].

| Year | Production (ton) | Export (ton) | Consumption (ton) | Stock (ton) |
|------|-----------------|-------------|------------------|------------|
| 2015 | 35,500          | 27,460      | 8,309            | 4,500      |
| 2016 | 37,076          | 27,259      | 12,748           | 3,747      |
| 2017 | 41,983          | 32,184      | 11,056           | 3,895      |
| 2018 | 47,388          | 34,706      | 13,491           | 3,261      |
| 2019 | 51,828          | 37,390      | 16,730           | 4,597      |

**Figure 2.** Integrated palm oil-based energy plantation [8].
In the logistics management and national supply chain of the biofuel industry, Life Cycle Cost Analysis (LCC) is useful for quantitatively measuring the economic impact on the entire production process, starting from the land use process for energy plantations, cultivation, to harvesting, bio-refinery, to optimization. Co-products as well as waste [9]. Policy recommendations are needed in optimization strategies starting from oil palm-based energy plantations that aim to increase the economic impact on the community through the concept of a circular economy to support the sustainability of the biodiesel and bio-hydrocarbon industries (Bio-gasoline/Gasoline, Bio-LPG and Bio-Avtur) in the future [1, 10].

2. Life cycle costing
Life cycle approach can be based on environment or monetary. Life Cycle Assessment (LCA) is a method for evaluating the inputs, outputs and potential environmental impacts of a product system throughout its life cycle (cradle to grave) [11]. There are many benefits from LCA both for industry and the environment, such as obtaining optimal and efficient production results, to help find continuous improvement so that we can protect the environment for the future [12]. The approach that look at the direct monetary costs involved with a product or service and not environmental impact is the LCC.

The LCC analysis of the national biofuel industry helps assess the economic impact to determine total production costs, from facility construction until the end of its economic life [9]. LCC also covers all costs associated with the exploitation of the resource (in this case, land use change / land use, energy plantations), procurement, utilization and end of life phase, together with the risks and externalities [13].

LCC analysis applied by adding externality variable can also provide comprehensive information on the cost structure of palm oil-based biofuels production, hotspot of biofuel production costs, as well as information costs that arise due to the impact of social, land use change, and the environment along the supply chain [13]. In the LCC there is also a measurement of cost benefit analysis (CBA) which is assessed from the entire life cycle by considering externalities (Figure 3). Moreover, there are several cost components included in the LCC which are presented in Table 1. In life cycle costs, the initial expenditures are the major cost.

![Figure 3. The economic limit of the biofuel production phase for LCC estimation [14].](image-url)
Table 1. Expenditure components included in the LCC.

| Expenditure category          | Description                                                                 |
|------------------------------|-----------------------------------------------------------------------------|
| Capital expenditure (Investment or acquisition) | Investigative work and Front-End Engineering Design (FEED)                   |
|                              | Property, plant, and equipment cost (land, buildings, machinery or machinery, equipment, etc.) |
|                              | Other investments (interest rates, inflation, etc.)                          |
|                              | Operating cost associated with the preparation and realization of assets, commissioning factory |
|                              | Training and capacity building                                               |
| Operational shopping         | Energy supply                                                                |
|                              | Water and wastewater treatment costs                                         |
|                              | Garbage disposal cost                                                         |
|                              | Service, cleaning, health and insurance cost                                  |
|                              | Safety and security costs                                                    |
|                              | Asset management                                                              |
| Maintenance expense          | Spare part, general and inspection, condition monitoring and service, downtime, and rest periods |
| Update issue                 | Machine repair and disassembly services, depreciation                        |
| Disposal expenditure         | Equipment disassembly, machine stoppage and building                         |
|                              | Cost of reuse and recycling of raw materials                                  |

3. Circular economy

Circular economy is an economic system in which products and services are traded and a closed cycle system designed to maintain as high as possible the value of a product, by-product, and other materials [15]. The big goal is how to create economic growth while maintaining the value of a resource or to create a longer life cycle, optimal reuse, renewal, and recycling of a product and material [16].

As shown in Figure 4, energy, economy and environment are important factors in industry. Energy encourages the development of various industries, but also causes environmental pollution [17]. One form of implementing the circular economy is to utilize waste into derivative products and renewable energy which at the same time adds to the total economic value and reduces the burden of environmental pollution [10].

![Figure 4](image-url)  
**Figure 4.** Integrated of energy, environment, and economic factor within the circular economic.
Indonesia has vast and productive land resources for the development of energy plantations. The biorefinery-based biofuel industry has a strong opportunity as an enabler for the development of a circular economy [9]. Biorefinery creates various derivative products as multiproduct throughout the process. The value chain of all products will build the total value chain of the biorefinery [18]. Meanwhile, the process and value chain will apply to specific impact areas. These economic impacts represent imaginary regional extents (e.g. districts, provinces, countries, etc.) or other boundaries. Analysis of economic circular indicate various levels limit the economic impact as shown in Figure 5 accommodate the sustainability standards [10].

Another example is a construction of a new Bio-CNG plant to implement the circular economy concept by reducing waste produced by the palm oil industry [19]. In addition, to reduce greenhouse gas emissions and significantly save the use of fossil fuels [20].

![Figure 5. Proposed outline of a circular economy model [21].](image)

Two benefits are obtained at the same time, namely savings in the use of diesel fuel in the palm oil industry, and in a sustainable manner, efforts to reduce greenhouse gas emissions. Applying the concept of a circular economy by reducing waste from the palm oil industry. Currently developing a new paradigm about the palm oil industry called Palm 5.0. Where by applying novel algae technology, it is considered to be able to manage palm oil waste into financial benefits [7].

The implementation of a circular economy in the life cycle of energy plantations and its derivative products helps to add to the total economic value and reduce the burden of environmental pollution. The implementation of the mandatory biodiesel program has contributed significantly to the reduction of diesel imports in Indonesia. The average of monthly diesel imports in 2019 decreased by 45% compared to that of 2018. Biodiesel managed to help reduce CO₂ by 14.34 million tons of CO₂e. In addition, it can save the country’s foreign exchange from import spending as much as IDR 63.4 trillion in 2020 [22]. In the labour sector, palm-based biodiesel can increase the workforce (farmers) to 1,207,812 people in 2020. Furthermore, there has been an increase in the added value of CPO by 9.45 trillion from 2016 to
2020 [22]. It is estimated that the circular economy can generate an additional Indonesian Gross Domestic Product (GDP) of IDR 593 trillion – IDR 638 trillion, and a GDP growth rate of 0.6% in 2030 [10].

4. Conclusions

Naturally, Indonesia has implemented a circular economy, but it is not structured, not optimal and not well quantified. The model that we have conceptualized from rural to national is sufficient to illustrate the concept of a circular economy from rural to scale quite well.

Through the modelling process, LCC provides a quantitative overview about the use of certain products with the concept of a biorefinery in various aspects, such as the economic, environmental, and social impact. Then the impact of micro and macro circular economy is expected to be applied in the entire life cycle and supply chain of the national biofuel industry because it is able to show opportunities for sustainable exploitation of natural resources.

5. Recommendation

Further elaboration of policy assessments of energy plantations by utilizing LCC help stakeholders to develop policies, strategies, and detailed activities involved in developing a system of circular economy. The government can also be assisted in assessing strategic policies, optimizing land functions through several systematic steps such as improving the governance of oil palm plantations. LCC also be the referee policy that is balanced between price procurement of biodiesel.

It is hoped that the biorefinery industry, in this case biofuel, will become a leading sector and have a broad impact in transforming the national economy. Increased productivity and competitiveness of the industrial sector of biodiesel or bio-hydrocarbon (Bio gasoline, Bio-LPG, Bio-Avtur), is one of the keys to accelerating the recovery of the national economy due to the impact of the current Covid 19 pandemic.

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