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Life Cycle Assessment of Automotive Diesel Oil (ADO) Process in Indonesia

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ABSTRACT

The oil and gas industry is an important sector in national development both as a fulfillment of energy needs for the community or industrial raw materials. The oil and gas industry is affected by the *crude distillation* stage , *high vacuum unit* , *hydrogen plant* , *hydrocracking* , *naptha hydrotreater* and platformer. Each unit requires fuel oil and fuel gas to produce heat. The results of combustion provide residual byproducts.

In the preparation of the stages of the oil processing process will cause various impacts on nature, environment and humans. The impact is the effect of residual discharge, which is a by-product of each processing unit. Increasing production will affect the impact of the oil processing industry. Then it is necessary to analyze and identify the impact of the oil treatment process using the *life cycle assessment* (LCA) method. The LCA analysis results will be followed up with an analysis of the impact reduction program.

Impact assessment with Life Cycle Assessment shows the gasoline process has a greater impact than the ADO / Diesel oil process. The biggest impact is the use of large fossil fuels with hotspots in the HCU solar process (66%).

Keywords: Automotive Diesel Oil, LCA, SimaPro

1. INTRODUCTION

The oil and gas industry is an important sector in national development both as a fulfillment of energy needs for the community or industrial raw materials. Increasing oil and gas production activities go hand in hand with increasing energy needs. In the last 10 years there has been an increase in energy consumption by an average of 7% [1]. The activities of the oil and gas industry generally have an impact on the environment. Both in the process of production, petroleum processing, storage and industries that use fuel oil (BBM). These activities will produce pollutants which are a source of environmental pollution. These pollutants will eventually enter the environment, if not managed properly it will cause problems in the environment. The oil processing sector is part of the activities of the oil and gas industry which conducts crude oil conversion activities into petroleum products. Products produced from the oil processing sector such as gasoline and ADO / diesel are both types of fuel which have a significant impact. The impact that arises comes from the production process and use of its products, which are mostly due to large energy use. The main energy that is widely used in oil processing activities is *fuel oil, feed gas,* and *gas mix* .

Concern for environmental impacts has increasingly become a world focus set forth in the sustainable development (SDG's) by the United Nations in 2012. In meetings that conducted by countries yielded 17 goals in sustainable development that need to be achieved [2]. One of the goals can be achieved by implementing clean production in an industry. Clean production is a preventive, integrated and continuously applied strategy for environmental management in every activity from upstream to downstream related to production processes, products and services to improve the efficiency of natural resource use, prevent environmental pollution and reduce the formation of waste in the source so that it can minimize risks to human health and safety and environmental damage (Ministry of Environment). Lack of industry *awareness* of clean production has not been sufficiently supportive. Nowadays, many industrial wastes that are *end-of pipe* or end at disposal without any processing. Some of the impacts that occur due to current industrial activities are *global warming* and *ozone depletion* , where both of these

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impacts cause climate change. Therefore, to support clean production it is necessary to analyze a production process from upstream to downstream with *life cycle assessment* (LCA). LCA is able to analyze the impact of a production process with the final results in the form of the biggest emission reduction scenario and the smallest impact magnitude.

Life Cycle Assessment (LCA) is an objective process to assess the environmental impact of a product, process, or activity. The assessment is carried out by identifying energy sources, use of *raw materials*, and disposal of the environment. According to ISO 14040, LCA is a technique used to assess environmental impacts related to a product. [3]. In addition, the method can evaluate and apply the possibility of environmental improvement [4]. So, by making LCA can avoid a shift in the impact of one phase of the product life cycle to another [5].

2. MATERIAL AND METHODS

2.1 Goal & Scope

The purpose of this study is to analyze the impact reduction program based on an analysis of the LCA study of the process of producing ADO.

2.2 System Boundaries

The LCA research for gasoline and ADO production is defined as the *gate-gate* , because it only discusses the closest production flow. In addition, the scope of the research only discusses the processing of crude oil without taking into account activities in exploration of production, distribution, and use.

2.3 Functional Unit

Functional units (FU) used in this study are mton / year. FU is the same for all scenarios, with inventory flows and impacts for scenarios calculated according to FU [6].

3. LIFE CYCLE INVENTORY

The flow of gasoline and ADO / Solar processes has a different chain, where the process has a longer process chain as shown in Figure 1.

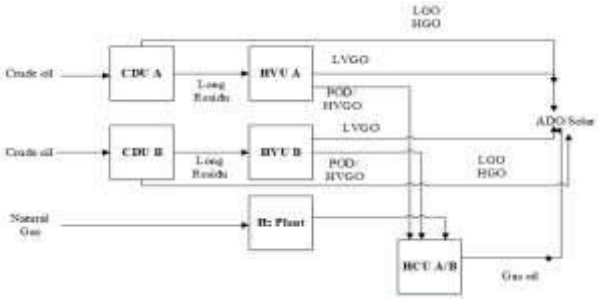

Fig 1: Automotive Diesel Oil process

However, the processing unit used is actually the same, here are the processes that occur in each processing unit:

1. Crude Distillation Unit (CDU)
   Distillation of *crude oil is* carried out on the CDU unit which functions to separate crude oil based on its boiling point.

Table 1 Life cycle inventory in CDU

Category	Input Data	CDU A	CDU B	Unit
Input	Crude Oil	0.09	185.40	Ton/yr
	Air	0.55	4.95	Ton/yr
Energy	Fuel Oil	3.96.E-04	2.17.E-04	M.Ton/yr
	Natural Gas	3.45.E-04	1.66.E-03	M.Ton/yr
	Refinery Gas	2.94.E-05	2.22.E-03	M.Ton/yr
Output	LGO	0.05	0.24	Ton/yr
	HGO	0.04	0.27	Ton/yr
Emission to air	CO_2	2.76.E-03	8.22.E-03	Ton/yr
	CH_4	-	1.38.E-07	Ton/yr
	N_2O	1.01.E-08	1.51.E-08	Ton/yr
	SO_x	2.87.E-06	1.97.E-06	Ton/yr
	NO_x	3.90.E-06	5.79.E-06	Ton/yr
	PM	4.23.E-07	6.02.E-07	Ton/yr

2. High Vacuum Union t (HVU)
   HVU serves to process *long residue* products from CDU by distillation under vacuum condition. The feed boiling point will be reached with a low pressure which is below 1 atm. The aim of the boiling point is to prevent *cracking* when heated too high to reach the actual boiling point.

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Table 2 Life cycle inventory in HVU

Category	Input Data	HVU A	HVU B	Unit
Input	Long residue	0.046	0.137	Ton/yr
	Air	0.276	1.108	Ton/yr
Energy	Fuel Oil	1.15.E-04	-	M.Ton/yr
	Chevron gas	1.89.E-04	6.23.E-04	M.Ton/yr
	Refinery Gas	6.19.E-06	8.68.E-04	M.Ton/yr
Output	LVGO	0.029	0.114	Ton/yr
Emission to air	CO_2	1.21.E-03	0.003	Ton/yr
	CH_4	3.14.E-08	-	Ton/yr
	N_2O	9.90.E-09	2.99.E-09	Ton/yr
	SO_x	1.10.E-06	1.20.E-08	Ton/yr
	NO_x	1.58.E-06	1.49.E-06	Ton/yr
	PM	1.70.E-07	1.49.E-07	Ton/yr
Emission to water	Air limbah	-	0.015	m3/yr

3. Hydrocracking Unit (HCU)
HCU is a catalytic cracking unit that processes HVGO raw materials from HVU. The process that occurs in HCU is a catalytic process and consumes hydrogen.

Table 3 Life cycle inventory in HCU

Category	Input Data	Production	Unit
Input	HVGO	0.36	Ton/yr
	Air	1.74	Ton/yr
Energi	Fuel Oil	3.62.E-03	M.Ton/yr
	Chevron gas	4.50.E-03	M.Ton/yr
	Refinery Gas	6.16.E-03	M.Ton/yr
Output	Solar	1.78.E-01	Ton/yr
Emission to air	CO_2	5.68.E-02	Ton/yr
	CH_4	1.14.E-06	Ton/yr
	N_2O	9.19.E-08	Ton/yr
	SO_x	2.75.E-05	Ton/yr
	NO_x	5.20.E-05	Ton/yr
	PM	5.52.E-06	Ton/yr
Emission to water	Air limbah	1.12.E-01	m3/yr

4. H_2 Plant
This unit serves to produce hydrogen that is used in the *hydocracking* unit (HCU). The input in this unit is water (H_2O) and natural gas (CH_4) with the *steam reforming* process . Hydrogen is produced for HCU to reduce the temperature of the *bed*.

Table 4 Life cycle inventory in H_2 Plant

Category	Input Data	Production	Unit
Input	Natural Gas	28.03	Ton/yr
	Air	0.07	Ton/yr
Energy	Chevron gas	2.44.E-03	M.Ton/yr
	Refinery Gas	2.99.E-03	M.Ton/yr
Output	H2	6.88.E-03	Ton/yr
Emission to air	CO_2	2.27.E-02	Ton/yr
	CH_4	3.06.E-07	Ton/yr
	N_2O	2.31.E-08	Ton/yr
	SO_x	8.88.E-08	Ton/yr
	NO_x	1.13.E-05	Ton/yr
	PM	1.13.E-06	Ton/yr

4. RESULT AND DISCUSSION

Environmental impact analysis will be elaborated based on the production flow, namely ADO / Diesel. Impact analysis using the Simapro application with the Eco-Indicator 99 (H) impact assessment method.

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4.1 Life Cycle Impact Assessment

Based on ISO 14042, the steps taken in the LCIA are characterization, normalization and weighting [6]. The following results are running on the LCA software:

a) Characterization
The value of the LCI will be converted into the amount of the impact according to the unit of each impact. The value of the endpoint impact amount is 236.95 MJ surplus (resources), 2.07 PDF * m2yr (ecosystem quality) and 0.0000737 DALY (human health).

b) Normalization
The value of characterization will be normalized to equalize units. The results of the normalization analysis of the impact values (endpoints) are predominantly sequential, namely resources (0.028), human health (0.0048) and ecosystem quality (0.000403). The most dominant impact is fossil fuels which are the impact of the endpoint of resources. Other dominant impacts are sequentially namely climate change, inorganic respirator, acidification, ecotoxicity, carcinogens, organic respirators, land use and minerals.

c) Weighting dan Single Score
The normalization value is multiplied by a weighting factor to obtain the impact value with the same unit namely the ecopoint. The weighting results showed that in every 1 mton of ADO / Solar produced an impact of 7.72 Pt, with the description of 5.64 Pt (resources), 1.92 Pt (human health) and 0.16 Pt (ecosystem quality). The biggest impact contribution comes from the HCU unit with a total impact value of 14.79 Pt.

The results of running LCA using SimaPro provide the same results between gasoline and ADO / Solar production processes. The impact of *resources* is the biggest impact, followed by *human health* and *ecosystem quality* . The value of each impact is 7.72 Pt (*resources*), 1.92 Pt (*human health*) and 0.16 Pt (*ecosystem quality*) . *Fossil fuels* are the biggest impact category due to the use of fuel oil (*low sulfur*), Chevron Gas and Gas Refinery. HCU contributed the biggest impact of *fossil fuels* , namely 10.707 Pt.

The impact of *human health* in the second position with 2 categories of dominant impacts is *climate change* (1.14 Pt) and *inorganics respirator* (0.77 Pt). HCU as the solar generating unit contributes the biggest *human health* impact , namely 1.15 Pt . The cause of the impact is due to the release of Greenhouse Gases (GHG). This GHG release is triggered from fuel combustion, which is in the gasoline production process which each unit uses fuel in the *furnace* to produce heat. The combustion byproduct produces CO_2 , CH_4 , NO_x and SO_x gas . The impact of *inorganics respirators is* caused by the release of inorganic gases into the atmosphere. Gas released into the air will be directly exposed to humans, causing interference with the respiratory tract.

The impact of *ecosystem quality* shows the lowest impact value than *resources* and *human health* . The factor of impact is based on the impact categories of *ecotoxicity* , *acidification / eutrophication* and *land use* . Value of each each of these impact categories is 0.072 Pt; 0.089 Pt and 0.0003 Pt . HCU is the largest unit contributing with an impact value of 0.119 Pt. Unit contribution to impact sequentially namely HCU, H_2 plant, CDU B, CDU A, HVU B and HVU A, like the following visualization.

4.2 Hotspot Analysis

The contribution of the processing unit based on the impact detail has been explained in the LCIA analysis section. Based on the results of *running it is* known the contribution of each processing unit as shown in Figure 4.

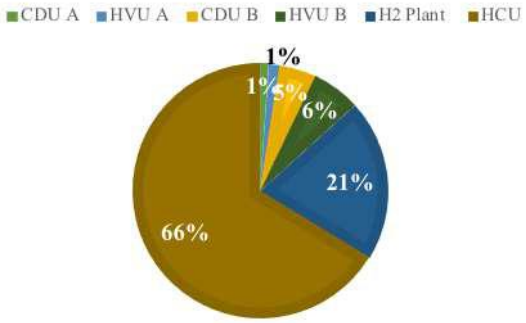

Fig 2: Contributions to the ADO / Diesel oil processing unit

The processing unit that provided the largest contribution was HCU of 66 %, which functions in processing LVGO into Solar. Determination of repair priorities can be done in the order of HCU, H_2plant, CDU B, CDU A, HVU B and HVU A. The ADO / solar process has a priority program to reduce the same impact as the gasoline process. *Fossil fuels* are the biggest impact, so there needs to be a reduction and / or alternative substitute for fuel. The program on fuel

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will affect other impacts such as *climate change* and *inorganics respirators* .

4.3 Recommendation Program

The process of producing ADO / Solar has a significant impact within 1 year. Impacts produced if not managed properly will increase and endanger humans, the environment and nature. Based on the LCIA results and HCU hotspot analysis, it contributes the most to the ADO/Solar. Program recommendations that can be proposed are by considering the priority of the contributing processing units. Priority for ADO / Solar process in the order of HCU, H_2 plant, CDU B, CDU A, HVU B and HVU A. The biggest impact from the activities of the oil processing industry is *fossil fuels* , with a value of 7.72 Pt (ADO / Solar). Recommendations for the impact reduction program focus on energy efficiency, as a form of decline and alternative types of fuel. The following programs are possible to be carried out at each processing unit.

a) HCU : Utilization of Hydrogen Excess Platforming for HCU [7] and Plenum Modification on HCU (personal interview)
b) CDU : Cleaning Pre-Heater (personal interview), Progressive Crude Distillation [8] and Modeling of Crude Oil Composition (personal interview).
c) Others : Flare Gas Recovery System (FGRS) [9] and Revitalization Burner (personal interview),

5. CONCLUSION

In this study the LCA method was used to identify impacts and determine the appropriate impact reduction program in the ADO / Solar production processes. In producing 1 mton of 1 mton of ADO / Solar produces an impact of 7.72 Pt. *Fossil fuels* are the most dominant impact of / Solar processes. Meanwhile, the processing units that contribute are 66% HCU (ADO / Solar).

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