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Reducing Environmental Impact on SME Metals Production Process Using Life Cycle Assessment and Analytical Hierarchy Process Method

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Abstract. *The ABC metal SME produces some wastes, such as liquid waste, solid waste, and smoke. The problem is hazardous waste dumped directly into the environment without any waste treatments, which had a terrible impact on the environment around its SME. Therefore, this research is proposed to improve the production process of metal that can reduce environmental impacts. The Life Cycle Assessment (LCA) method is developed to identify all the processes that impact the environment and calculate the energy used. The values of environmental impact are calculated using Simapro 9.0 Software. In addition, the Analytical Hierarchy Process (AHP) method is employed to determine the best alternative fuel according to four criteria: temperature, price, emission, and fuel consumption. The results show the process that has the most significant environmental impact is the metal smelting process. It is caused by the source fuel in this process was used oil. The usage of used oil can be the source of air pollution that causing health problems in the respiratory tract, such as bronchitis and asthma. However, some alternative fuel was proposed; however, the fuel gas is the best alternative, according to expert opinions. For managerial insight, this research can be a suggestion for SME to choose the best fuel in the production process that considering economic and environmental aspects.*

Keywords: *analytical hierarchy process, life cycle assessment, metal, oil, small-medium enterprises*

I. INTRODUCTION

Industrial developments in Yogyakarta is increasing rapidly, especially in the field of the metal industry. The use of aluminum and metal or aluminum alloy in the industrialized world continues to grow. This situation may be positive to improve or expand their use of resources; however, it produces a negative impact of pollution and resource depletion or degradation (Gerasimova, 2017). According to data from the ministry of environment and forestry, in 2017, Yogyakarta obtains environmental quality index value amounted to 49.80% which is predicated very poorly (Ministry of Environment and Forestry of the Republic of Indonesia, 2018). In Europe, SMEs contribute 60% to 70% of the total environmental impact (Daddi et al., 2016). Judging from the website http://umkm.jogjakota.go.id, in the city of Yogyakarta, 191 SMEs metal crafts and electronics are scattered in the city of Yogyakarta in the district of Kota Gede, Kraton, Mantrijeron, Mergangsan, Tegalrejo, Umbulharjo, Wirobrajan called craft industry center (copper, aluminum or craft kitchen tools), which consists of small and medium industries. SMEs focused on household appliances such as pans, and pots only amounted to 60 SMEs that are members of UPT metal. Diverse types of products cause multifunctional processes into different products because not all functional streams are part of the same product system (Castanheira et al., 2015).

Types of iron and steel industry can be a potential source of pollution of air emissions, wastewater, and solid waste (Ester, 2006). Iron and metal industry is one of the industry's most energy-consuming, which has the most significant contribution to emissions of greenhouse gases (GHG) such as CO_2 CH_4 and N_20 in the atmosphere (Siregar, 2007). The environmental impact factors or parameters related to metal production processes affect the cradle-to-gate environmental impact of the process. These include grade ore, the source of electrical energy,

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fuels, and transport of materials and process technology (Norgate, Jahanshahi, & Rankin, 2007). Aluminum is a material that can be recycled many times without losing its quality ((EAA) 2008). The main process of aluminum production is divided into two stages, namely the process of Bayer alumina refining and aluminum smelting is the process hellel herrout (Habashi, 1997).

The process of metal casting in metal ABC SME was done traditionally. Metal casting activities traditionally give their hazards such as high temperature, infrared radiation, or ultraviolet (Damanik et al., 2015). Lack of knowledge in the field of metal casting causes air pollution through the chimney or air inhaled directly by workers in SMEs metal ABC (Damanik et al., 2015).

Raw materials used in SMEs ABC metal is cast aluminum, aluminum scrap, and scrap metal. Small-scale metal casting industries that utilize raw materials scrap iron produce by-products in the form of solid waste and air pollution that are harmful to the health of both the environment and worker (Fatkhurrahman & Juliasar, 2014). Based on research, cast aluminum has a melting point at a temperature of 640°C (Mandala & Siradj, 2016). Metal smelting processes that require high temperatures which affect the declining quality of the gas NO_2. The exposed worker gas pollution NO_2 in a long time impact on health and cause diseases such as bronchitis and asthma (Prayudi, 2011). The impact of exposure that removes the metal dust through the chimney accumulating in the atmosphere, so the impact on the decline in air quality in the area of the metal casting industry Ceper Klaten to be a form of NO_2, SO_2, CO, O_3, NH_3, H_2S, and noise (Damanik et al., 2015). Inhalation of aluminum dust in large quantities and a long time can cause disturbances in the respiratory tract, such as cough and shortness (Ulfah, 2017). Research (Ambarwanto et al., 2016) show that blood Pb levels in effect with hypertension in metal foundry workers. The presence of iron and steel smelting industry provides a major change to the conditions and environmental quality. These changes include air pollution, the development of germs, hygiene disturb the environment, and natural beauty (Paramitha, 2013).

The metal casting process must be balanced with an evaluation to reduce environmental impact. Life cycle assessment is the appropriate methodology to assess the resource efficiency of products and services in a life cycle approach (Campitelli et al., 2019). LCA is used in the analysis process of gate-to-gate, which makes it possible to compare the various processes that provide similar functions and choose the most environmentally friendly or most resource-efficient. LCA is also used to identify priorities for environmental improvements in the working process (Jacquemin et al., 2012).

Previous studies using the LCA method performed by (Campitelli et al., 2019) to find the efficiency of resources used in metalworking processes in Germany. While in Tuscany (Italy), the LCA method is as a tool to evaluate the environmental impact on SMEs (Daddi et al., 2016). Application of the LCA method for the production of automotive components to the evaluation process with sub-suppliers of SMEs was made by Alberto to determine the production process from an environmental standpoint (Simboli et al., 2015). In Surakarta Indonesia, the research is to improve the awareness of SMEs on the environment that have been carried out by an SME (Matsumoto et al., 2017).

Firstly, the metal ABC SME uses petroleum, but the supply is decreasing, which makes this SME find another fuel to run the production process. Used oil, which is a waste coming from the motor fuel containing heavy metals from the motor engine (Gede et al., 2016), is employed as fuel in the aluminum smelting process. This used oil has potentially polluted the environment and harmful to human health. By reducing the use of fuels that are less environmentally friendly and to minimize the waste generated in the crucible production process, there is a need for the implementation of sustainable development. According to (Burchart-korol, 2011), sustainable development is a development that principled process to meet the needs of the present without compromising the needs of future generations.

Research on metal SMEs in Indonesia has often been done, but rather the application of occupational health and safety (OHS). Research to evaluate the processes that cause environmental pollution in SMEs is still a little metal. Use of LCA methods to analyze the environmental impact, it is rarely applied to the ABC metal SME. Therefore, this research has the objective of determining the best alternative fuel that reduces the impact on the environment that occurs in ABC metal SME by considering the temperature, prices, emissions, and fuel use.

II. Research Method

The research was conducted on one of the metal SME in Yogyakarta. ABC metal SME selected as research sites for used oil fuel use and has the highest pollution levels based on data from the Department of Environmental and Forestry (see Table 1).

According to data from ministerial regulation number 13 / MEN / X / 2011 the threshold value of metal dust particles is = 10 mg / m^3 = 1 BDS Inside a Million (Parts of vapor or gas per million volumes of contaminated air) and = 0.25 mg / m^3. Data can be seen in the attached data on emission threshold values. The emissions from the pan production process in ABC Metal SMEs exceed the threshold and are considered harmful to health.

This research was conducted with the past couple of stages. Starting from field studies, identifying the problem, determining the goals and scope, searching for life cycle inventory, life cycle impact assessment analysis, data processing with software Simapro, and determining the best alternative to the AHP (see Figure 1).

This study uses the LCA method used to identify the entire process that impacts on the environment and to calculate energy usage. The results of the LCA method will be analyzed using Simapro 9.0 software to identify all the processes that affect the environment and calculate the energy used.

The alternative solutions that have some criteria for each alternative approach are analyzed using AHP. The method used in conducting

Table 1. Emissions Results

No.	Test results	Parameter		
		Particle	SO_2	NO_2
		mg / m^3	mg / m^3	mg / m^3
		TP / 0 = 350	TP / 0 = 800	TP /) = 1000
1	SME A	48 850	9,350	5122
2	SME AB	10,673	2,039	5375
3	ABC SME	1450.357	13 257	17 403

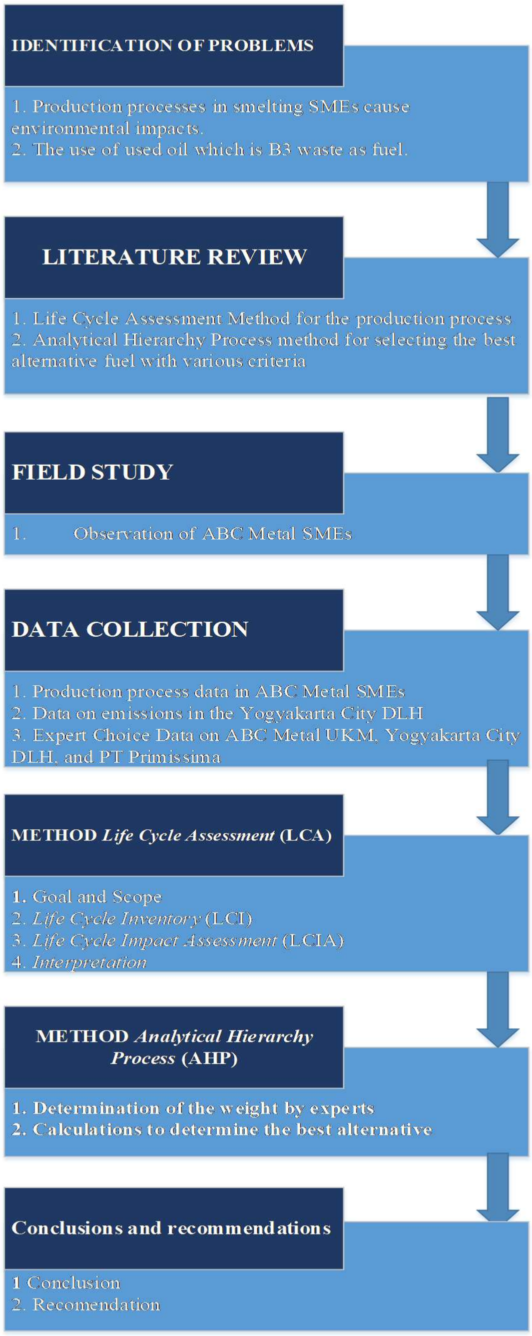

Figure 1. Stages of research

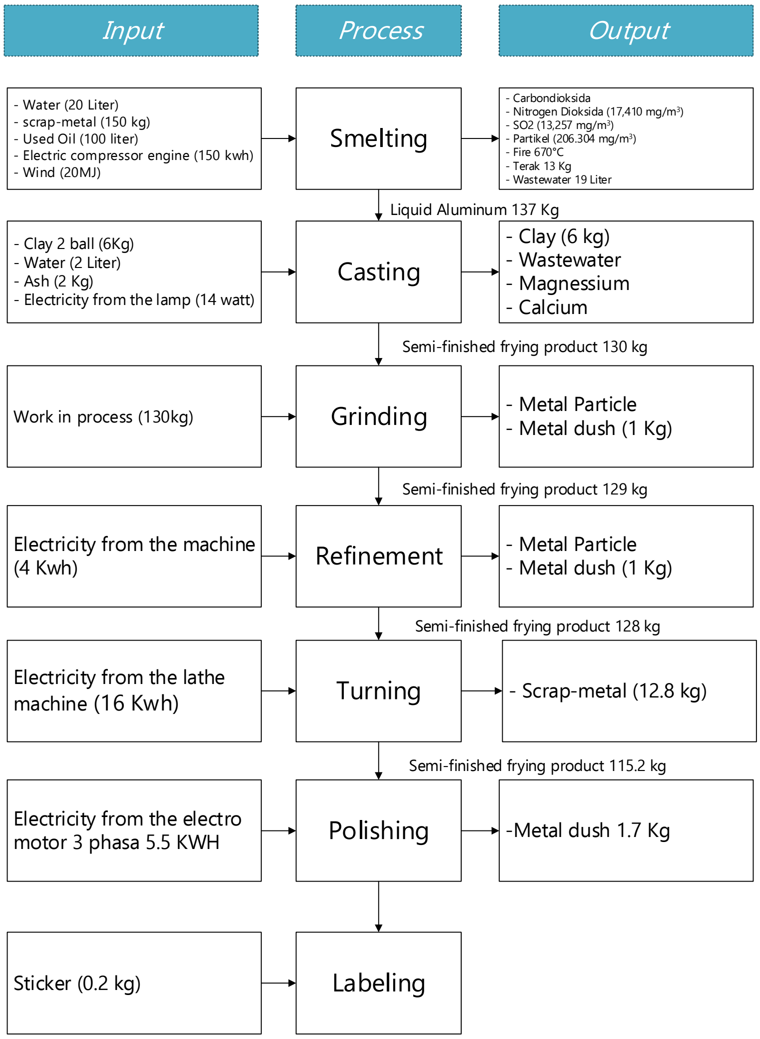

Figure 2. Life Cycle Inventory

interviews with experts from companies and environmental agencies to determine the weight that the results are considered to represent for each criterion (Tartiarini et al., 2016). AHP is chosen because it is regarded as an effective tool for decision-making in determining the best fuel alternative. AHP allows consideration of quantitative and qualitative data in the ranking of alternative options (Linh, 2019).

III. Result and Discussion

This study uses the LCA method in which the data processing with LCA methods will be identified to determine the processes that have the most significant impact on the environment. According to Wanzel method of LCA, there are several lists of impact category like The "Leiden List" (SETAC-Europe 1992), The "Nordin List" (Lindfors et al. 1995), The SETAC "Default List" (Udo de Haes 1996), The "EDIP list" (Wenzel et al. 1996), and the ISO 14047 list (preliminary) (ISO 1999). Of the five that list, select the "EDIP List" (Wenzel et al. 1996) because it is in accordance with research conducted, namely the industrial sector (Hoffmann & Schmidt, 2003). The data in this study conducted in several stages, namely:

Goal and Scope

Goal and Scope contain the purpose of the LCA study should be clearly defined (Hoffmann &

Schmidt, 2003). As the reason for the research for what and to what the study., Scope contains an explanation of the study, methods used, and limits (Putri & Lingkungan, 2017). This research concern about the environmental impact and the implementation of OHS at some SMEs still deemed less. This study aims to determine the processing of the metal SMEs that have environmental impacts to seek the best alternative to reduce the impact on the environment. This study uses the LCA method to limit the impact Assessment is air pollution, human toxicity, global warming, and water pollution. The Scope of this research is the process of manufacture of products made of metal on ABC SME in Yogyakarta.

Life Cycle Inventory (LCI)

At LCI included all inputs and outputs that can cause an impact during the life cycle of a product (Luglietti, Rosa, Terzi, & Taisch, 2016). LCI phase involving the compilation and quantification of inputs and outputs for a particular system product throughout its life cycle (Hoffmann & Schmidt, 2003). Figure 2 shows steps in the manufacture of metal in one of the SMEs in Yogyakarta, which produces equipment made of metal.

Life Cycle Impact Assessment (LCIA)

The purpose of LCIA is to provide additional information to help the assessment results to understand the LCI better. LCI on the environment (Luglietti et al., 2016). The calculation of the value of the environmental impact of the manufacturing process of metal performed using software SimaPro. Here are the results for the LCIA SimaPro software output.

Classification. Input-output data from LCI categorized by the type of impact on the environment (Lee & Inaba, 2004). Categorization was chosen by six impacts, namely Global warming (GW), human toxicity of water (HTA), human toxicity of soil (HTS), human toxicity water (HTW), chronic ecotoxicity water (EWC), and resource (Rsc). See Table 2 for the impact category.

Impact classification category based on the determination, it was found that the largest category of impact on the process of smelting and casting metal.

Table 2. Determination of impact category

Inventory Process Parameters	Impact category					
	GW	HTA	HTW	HTS	EWC	RSC
Smelting	O	O	O	O	O	O
Casting	O	O	O	O	O	O
Filing		O				
Rarefaction	O	O		O	O	
Lathing	O		O			
polishing			O			
Labeling						

Table 3. Impact Category and Unit

Impact Category	unit
Global warming 100a	Kg CO2 eq
Human toxicity air	person
Human toxicity water	m^3
Human toxicity soil	m^3
Ecotoxicity chronic water	m^3
Resources	PR2004

Characterization. After seeing the results of the Life Cycle Inventory, characterization has 6 impact assessment that is global warming 100a, human toxicity water, human toxicity air, human toxicity soil, ecotoxicity water chronic, and resources (all). See Table 3 for the impact category and units of software Simapro.

Normalization. Normalization is a comparison of selected impact indicators. This stage normalizes the results of the indicator by dividing by the reference value selected, of normalization with Simapro software, the result of an impact category in Table 4.

Weighting. Weighting and single score are weighting for each of the impact categories. This weighting is important because the impact category must also reflect the study objectives and values stakeholder. Weighting and a single score are done to get an equal impact comparison. A single score is the result of the weighting score based on the activity process. The calculation result from Simapro software is an impact category that is presented in Table 5.

After seeing the weighting Simapro Software

Table 4. Results are normalized calculation

	Impact category					
	GW	**HTA**	***HTW***	***HTS***	***EWC***	***rsc***
Smelting	0.0003	0.0005	0.0063	0.0003	0.0022	0.0029
Casting	0.0001	0.0001	0.00169	7.92E-05	0.000579	7.67E-04
Filing	-2.39E-06	-2.63E-09	1.97E-07	-1.63E-08	-3.99E-08	-6.16E-06
Rarefaction	0.000189	-0.0002	0.00508	1.26E-03	0.00121	-9.30E-07
Lathing	0.000474	-0.00019	0.000139	-1.22E-04	4.34E-03	-1.68E-06
Polishing	-2.61E-06	-4.85E-10	2.63E-07	-1.92E-08	-4.57E-08	-6.78E-06

Table 5. Weighting results Simapro Software

	unit	*impact category*					
		GW	**HTA**	***HTW***	***HTS***	***EWC***	***rsc***
Smelting	MPT	0356	0558	8:16	0353	0	0
Casting	MPT	0096	0:15	2.2	0.095	0	0
Filing	MPT	-2.62	-0.0028	0256	-0.0196	0	0
Rarefaction	MPT	0208	-0166	6.61	0151	0	0
Lathing	MPT	0052	-2.1	1.8	-0146	0	0
Polishing	MPT	-2.87	-0.0005	0342	-0023	0	0

9.0 results, processes have a significant impact on the impact of human toxicity on the water category. Processes have a major impact on that metal smelting process.

The metal melting process has several high weight to some criteria: (1) The highest weighting is on human toxicity of water due to the use of water is fired into the smoke of burning to reduce residual smoke from burning causes an increase in the level of water pollution, (2) The second highest weighting is human toxicity air. Human toxicity on-air and the pollution caused by the use of waste oils as the base material. So that the combustion is hazardous, besides the hot furnace will increase the content of NOx gases that are harmful to the workers, (3) The third highest weighting was human toxicity soil. Smelting contaminated wastewater discharged directly into rivers that affect the quality of the soil around SMEs, and (4) The fourth highest weighting is Global warming 100a. Smoke from burning fuel oil that is not exposed to water will be concentrated in an area so that the gas emissions in the atmosphere will also accumulate that affect global warming. Besides, the hot furnace will cause a reaction formation of NOx gases in the air.

The metal melting process has several high weights to some criteria: (1) The highest weighting is on human toxicity of water due to the use of water as a lubricant where soil mold and mold-making materials main mix. Pus mold making use of materials of clay, water, and ash. The result of this mixing of residual water is dangerous, (2) The second highest weighting, namely global warming. Hot molten metal from the furnace before pouring into the mold will cause reactions forming NOx gases in the air, and (3) The third highest weighting was human toxicity soil. The former unused mold containing a mixture of harmful substances.

Interpretation. Interpretation is the last step of the LCA procedure, where the results of the LCI and LCIA are summarized and discussed as a basis for conclusions (Luglietti et al., 2016). From the analysis of the environmental impacts of the above, it is known that the main problem the cause of environmental pollution in ABC SME metal is used oil fuel use in the metal melting process. Therefore alternative improvements will be focused on making improvements to the process. Alternative improvements were made

Table 6. Recommended options for improvement

Activity	Alternative Repair	Gains / Loss
The use of oil as fuel	The use of biogas as a fuel	Reducing the impact of environmental pollution in air, soil, and water Reducing the risk of disease for workers. The cost of fuel is more expensive.
The use of clay as a raw material mold while	The use of steel or metal as the base material, permanent mold	Reducing the impact of environmental pollution on land and water Better casting results and relatively the same. The use of more practical The shape of the mold cannot be changed
Activities without gear OHS	To disseminate the use of tools appropriate safety standards	Reduce the risk of short-term and long-term employees. The procurement of equipment safety requires an additional fee.
Standard operating procedure (SOP)	Improvement and supervision of the implementation of SOP	Reducing the risk of accidents and disease in workers (Damanik, 2016)
Hazardous and toxic waste management	Creating a temporary shelter hazardous and toxic Apply for a license temporary storage area hazardous and toxic waste	Reduce environmental pollution caused by hazardous and toxic waste Require time and money to get permits Costs for waste storage make dangerous and toxic waste
Metal industry	Relocation of industrial locations	Reducing industrial waste pollution (Fitriyani et al., 2016)

Table 7. A list of criteria for fuel

Name of Fuel	Temperature	Price (Rupiah)	Emission	The use of fuel
Coal	700 ° C	1350 / kg	NO_2 = 22.462 mg / m^3 SO_2 = 29.118 mg / m^3 Particles = 200.56 mg / m^3 An Opacity = 14% Crust: 613 kg)	43 kg
Used oil	670 ° C	1500 / Liter	NO_2 = 17.410 mg / m^3 SO_2 = 13.257 mg / m^3 Particles = 206 304 mg / m^3	12.5 kg
Liquefied Petroleum Gas (LPG)	640 ° C	11583.3/ kg	NO_2 = 10 425 ppm SO_2 = 5,858 mg / m^3	1.68 Kg

based on the results of research and discussion with the owner of the metal SME to resolve or reduce the environmental impact of the source of The problem.

Recommendations on replacement fuel in metal smelting process were selected based on four criteria: temperature, price, environmental impact, and fuel use. Based on the four types of criteria, the output/input of each fuel is listed in Table 6.

Alternative selection using Analytic Hierarchy Process

Weighting is done by a discussion with the head of the field PT. Primissima (Persero) and the Pollution Control Sections of water, air, and environmental damage Environment and Forests Office of the city of Yogyakarta and owner of ABC Metal SME.

Table 8. Competence respondents for weighting AHP

No.	Office	Name	Originally Agencies
1	P2K3 head PT.Primissima	Sigit Yuwono	Primissima PT (Persero)
2	Pollution Control Sections of water, air, and environmental damage	Ninik Sri Handayani	Environment and Forestry Office of Yogyakarta
3	Owner of ABC SMEs	Aris N.	ABC SMEs

Selection decisions hence with the AHP method, is used to determine the best fuel recommendations. Step workmanship with the AHP method draws on research (Munthafa & Mubarok, 2017).

The stages of the AHP method

We are creating a Hierarchical Structure. The basis for selecting criteria and alternative fuels in the hierarchical structure is based on discussions with ABC Metal SME owners and references from previous research. Figure 3 presents the hierarchical structure.

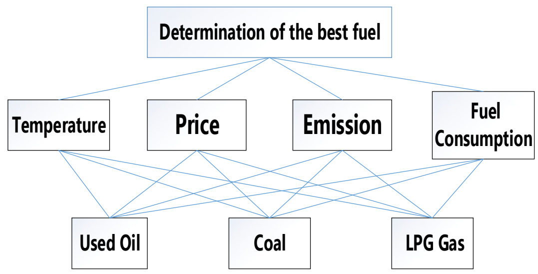

Figure 3. Hierarchical structure decisions

Filling weight among criteria can be seen in Table 9.

Table 9. Inter-criteria weights

	Temp.	Price	Emiss.	Fuel Consump.
Temperature	1	3	1	2
Price	0.33	1	1	1
Emission	1	1	1	3
Fuel Consumption	0.5	1	0.33	1

Table 10 shows the result of the normalization calculation to find the eigenvalue of the average value relative weight for each row based on criteria. Then, calculate the average eigenvalues in each row, as shown in Table 11.

Table 10. Normalization matrix

	Temp.	Price	Emiss.	Fuel Consump.
Temperature	1 / 2.83	3/6	1 / 3.33	2/7
Price	0.33 / 2.83	1/6	1 / 3.33	1/7
Emission	1 / 2.83	1/6	1 / 3.33	3/7
Fuel Consumption	0.5 / 2.83	1/6	0.33 / 3.33	1/7
Total	1	1	1	1

Table 11. Eigenvalues

Criteria	Temp.	Price	Emiss.	Fuel Consump.	Average
Temp.	0.353	0.5	0.3	0.286	0.36
Price	0.117	0.167	0.3	0.143	0.182
Emission	0.353	0.167	0.3	0.429	0.312
Fuel Consumption	0.177	0.167	0.099	0.143	0.146
Total	1	1	1	1	1

After obtaining the average value, then multiplying the initial comparison with the matrix at the average value. Hence,

Initial matrix x matrix average value

$$\begin{pmatrix} 1 & 3 & 1 & 2 \\ 0.33 & 1 & 1 & 1 \\ 1 & 1 & 1 & 3 \\ 0.5 & 1 & 0.33 & 1 \end{pmatrix} \begin{pmatrix} 0.36 \\ 0.18 \\ 0.31 \\ 0.15 \end{pmatrix} = \begin{pmatrix} 1.509 \\ 0.758 \\ 1.293 \\ 0.611 \end{pmatrix}$$

Calculating the consistency hierarchy

Counting: (A) (wT), with:

n = 4; RI = 0.99

$$t = \frac{1}{4}\left(\frac{1.51}{0.36} + \frac{0.76}{0.18} + \frac{1.29}{0.31} + \frac{0.61}{0.15}\right) = 4.172$$

Calculating Consistency Index

$$CI = \frac{(4.172-4)}{3} = 0.057$$

Calculating Ratio Consistency

$$CR = \frac{0.057}{0.99} = 0.058$$

Because of the consistency ratio value less than 0.100, the calculation results are considered correct and consistent.

The results of the normalization calculation are to find the eigenvalue of the average relative weight value for each line based on criteria.

Table 12. The total value of the alternative criteria

No.	Fuel name	Temp.	Price (Rp)	Emiss. (SO_2)	Fuel Consump.
1	Coal	700° C	1250	29.118	43 Kg
2	Used oil	670° C	1500	13.257	12.5 Kg
3	LPG	640° C	11583	5.858	1.68 Kg
	Total	2010° C	14833	48.233	57.18 Kg

Table 13. Normalization Matrix Alternative

No.	Fuel name	Temp.	Price	Emiss. (SO_2)	Fuel Consump.
1	Coal	0.348	0.0872	0.604	0.75201
2	Used oil	0.333	0.1047	0.275	0.21861
3	LPG	0.318	0.8081	0.121	0.02938
	Total	1	1	1	1

Table 14. Alternative Eigen Value

No.	Fuel name	Temp.	Price	Emiss. (SO_2)	Fuel Consump.
1	Coal	0.348	0.0872	0.604	0.75201
2	Used oil	0.333	0.1047	0.275	0.21861
3	LPG	0.318	0.8081	0.121	0.02938
	Total	1	1	1	1

After that, we do calculate alternate Eigen value-criteria, with multiplication, a combination of criteria and alternatives.

Table 15. Alternative Eigen

No.	Fuel name	Temp.	Price	Emiss. (SO_2)	Fuel Consump.
1	Coal	0.125	0.0158	0.188	0.11004
2	Used oil	0.12	0.019	0.086	0.03199
3	LPG	0.115	0.1468	0.038	0.0043

Standard weighting value (Chen et al., 2009),

Table 16. Standard weighting

Grade	Priority
Extreme High	0513
High	0261
Average	0129
low	0063
Extreme Low	0033

Table 16. Values importance weight

Fuel	Temp.	Price	Emiss.	Fuel Consump.	Total Value
Coal	0513	0513	0129	0129	1,284
Used oil	0261	0261	0261	0261	1,044
LPG	0129	0129	0513	0513	1,284

Based on the calculation method of AHP obtained final weighting value of each alternative as Table 17.

Table 17. Total value

No.	Alternative	Total value
1	Coal	1,284
2	Used oil	1,044
3	LPG	1,284

Determining the best alternative fuels are selected based on the total weighting of the highest value. The results of the weighting value of the three alternatives there are similarities between the results of the coal and LPG. In terms of other options with environmental friendliness, LPG is much more environmentally friendly. Alternative fuel that provides the best and most environmentally friendly is LPG.

IV. CONCLUSION

Based on results and discussion of the research above, it can be concluded that the environmental pollution occurs in metal smelting process with the value of global warming's impact assessment 100a of 0.356 kg CO2 eq, human toxicity air of 0.558 persons, human toxicity water 8.16 m^3, and human toxicity soil of 0353 m^3. From the analysis, the melting process metal contamination is caused by the melting process's fuel source, which uses the essential ingredients used oil.

Burned used oil is causing air pollution affecting the health of workers and lower the environmental quality. Based on data from the environmental and forestry department, air pollution values obtained with the metal melting process of used oil fuel amounted to 17.410 mg / m^3, amounting to 13.257 mg / m^3, and particles of 206 304 mg / m^3. Hence, the comparison to determine the best alternative. Fuel switching is done by comparing the coal, gas, and used oil by using the AHP method. Results of the comparison of three alternative fuels, coal and LPG has the same weight ratio that is 1.284. From the weight ratio criteria, LPG is more environmentally friendly. Therefore, alternative fuels to obtain the best and most environmentally friendly is LPG.

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