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A Comparative Study of Life Cycle Impact Assessment using Different Software Programs

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A Comparative Study of Life Cycle Impact Assessment using Different Software Programs

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Abstract. Life cycle analysis (LCA) is a powerful method to quantify impacts based on material input in the process production. The results of midpoint impact analysis categories vary from global warming potential to water footprint. In addition, endpoint impact analysis also provides quantitative results of general environmental impact assessment which is possible to be written as additional results and a deeper analysis in Government or Company Environmental Report. There are many types of software that can be used for impact analysis, for example, SimaPro, OpenLCA, Gabi, Umberto, etc. In this study we analyze the difference of impact assessment result using Simapro and OpenLCA with same material input data and similar database. The results of the environmental impact analysis using the CML-IA baseline V3.05 / EU25 method in the SimaPro software after normalization are as follows: global warning impact contribution 0.0206, ozone layer depletion 0.0002, acidification 0.0016, and eutrophication 0.0134. Meanwhile, the analysis results from OpenLCA software after normalization are: global warming impact contribution 4,5071 x 10^{-13}, ozone depletion 1,0794 x 10^{-14}, acidification 3,2878 x 10^{-13}, and eutrophication 8,4541 x 10^{-13}.

Keywords: Life cycle impact assessment, life cycle analysis, software, comparison

1. Introduction

Environmental Impact Analysis, or known as AMDAL, the method used to asses environmental impact, needs to be reviewed again. This is due to the fact that the impacts studied in the Environmental Impact Analysis are only represented qualitatively, and not stated quantitatively. Furthermore, this method has some weaknesses in determining the possible impacts that might occur and determining the priority impact that shall be dealt first is quite difficult. Based on this fact, a new method is needed in analyzing the environmental impact of an activity. Life Cycle Assessment (LCA) meets the criteria of quantitative analysis needed in an environmental impact analysis. LCA is proven for being used in many areas of activity, in example power to gas power plant [1], municipal solid waste management [2], and low carbon technology [3]. This is because LCA's results are capable to predict environmental impacts along with their values or weights, quantitatively. Moreover, the results of LCA method are shown in the form of a graph where the hotspots can be found easily. So, this feature of LCA will make it easier for users to determine recommendations that would effectively reduce the environmental impacts from the activities.

LCA can be separated into several stages. The stages are: (1) Goal and Scope Definition, (2) Inventory Analysis, (3) Impact Assessment, and (4) Interpretation for Improvement. The first stage, goal definition, defines the purpose, goal and boundaries of the assessment. The second stage is data collection and the calculation of the emissions and burdens associated with every unit process system related to the product. The impact assessment evaluates the potential and actual environmental impacts. The final stage of LCA is the improvement assessment, where the changes that are needed to bring about environmental improvements are evaluated and reviewed.

The methodology comprises the following four phases: (1) Goal and scope definition: Defining the goal and scope of the study (defined by ISO 14040); (2) Inventory analysis: Making a model of the product life cycle with all the environmental inputs and outputs. This data collection effort is usually referred to as life cycle inventory (LCI) (defined by ISO 14041); (3) Impact assessment: Understanding the environmental relevance of all the inputs and outputs. This is referred to as life cycle impact assessment (LCIA) (defined by ISO 14042); (4) Interpretation: The interpretation of the study (defined by ISO 14043).

Environmental problems such as global warming and waste are becoming more and more of an international interest. As a consequence, companies are progressively improving their environmental practices and behaviors by starting to use life cycle management in their organization. LCA is a tool for environmental analysis of products at all stages of their life cycle including the sourcing of raw materials, manufacturing, distribution, transportation, and end-of-life disposal and it has been standardized in ISO 14040 series. Because there are many stages of process that must be analyzed in an LCA, government and companies need the tool or software to calculate the inventory and impact assessment and to determine energy and mass balances on an item or model and allocate emissions, energy uses, etc.

An LCA can be both analyzed manually or using a specific software. However, since in Indonesia the impact factors are not defined yet, a manual LCA is difficult to be implemented. An LCA software is recommended as an approach in Indonesian industries since the impact factors are available eventhough they are still using foreign impact standards.

But nowadays there are many different software programs available to perform LCA and companies may not know which one is the most suitable for their organization. Consequently, the goal of this research is to study the different software applications to help companies choose the most suitable one. This research analyzes and compares 2 software tools. But the differences of the database of each program will affect the results and appropriateness of one software to another. The two software programs chosen for this research are SimaPro and Open LCA.

SimaPro is one of the most popular or commonly used software programs which has been in the market for more than 15 years and has high license pricing. It is provided by PRé Consultants. It has many advantages, for example, being more flexible, attached with many databases, can easily connect with other tools, is user friendly, generates transparent results, etc.

Open LCA is a freeware package (open source) and a widely known software tool that is easy to handle and it allows the user to calculate all the stages associated to LCA. Another advantage of this tool is that it offers users the possibility of working with different databases, such as those used by GaBi, and others. Initially Open LCA was designed for calculating the environmental impact of products and processes, but it can now add economic aspects. In addition, it has a feature-rich, technically up-to-date introduction to the software. It also has the broadest selection of relevant, consistent LCI and sustainability databases available worldwide. OpenLCA has been developed by GreenDelta since 2006 with the support of PE International (makers of GaBi), PRé Consultants (creators of SimaPro) and UNEP (United Nations Environment Programme). OpenLCA are available on different levels, such as process, product system, project, and impact method database. The method pack for impact assessment is available for free, but not included by default in openLCA. One of the advantageous features of OpenLCA is that the process networks and graphical modelling can be created automatically and manually.

Both software programs are recommended by experts since both of them are user friendly and supported with an original database since they are used as life cycle assessment, social life cycle assessment, life cycle costing, carbon & water footprint, product environmental footprint (PEF), and environmental product declarations (EPD). Previous research studied the result comparison between GaBi and SimaPro [4]. However, the result comparison of SimaPro and OpenLCA need to be studied further for validating the results since these two software programs began to be introduced in Indonesia.

2. Material and Methods

General life cycle impact assessment (LCIA) consists of four consecutive steps: classification, characterization, normalization and weighting. In classification, all substances are sorted into classes according to the effect they have on the environment. A cause-effect pathway shows the causal relationship between the environmental intervention (for instance, the emission of a certain chemical) and its potential effects. In characterization, each impact is quantified using a specific factor which reflects their relative contribution to the environmental impact and provides a result specific to the concentration of the substance. In normalization, a quantified impact is compared to a certain reference value; therefore, all impact has the same value and can be compared to each other. Weighting entails multiplying the normalised results of each of the impact categories with a weighting factor that expresses the relative importance of the impact category. The weighted results all have the same unit and can be added up to create one single score for the environmental impact of a product or scenario. In this research, we compare the results of impact assessment from SimaPro and OpenLCA software programs since both programs are widely used and the databases are globally provided.

In this study, the application used in processing data for LCA analysis is Simapro with business license. This version allows users to change and add up materials to the database according to the characteristics of the material that will be inputted. This feature is quite important, considering that Indonesia does not have a database for the oil and gas industry, power plant and other sectors yet. It is expected that with the use of business licensed SimaPro, the LCA analysis that will be conducted can provide results that are representative of the actual conditions in Indonesia.

The scope of this research is as follows: (1) The LCA study is carried out in the processes of exploration and production of oil and gas in general, which include Wellhead Platform; Production Separation; Gas Mercury Removal; Booster Compressor; Sales Gas Compression; and Water Treatment; (2) The data value of input and output in each process unit are dummies; (3) The software programs used are SimaPro full version (Business Licence) and OpenLCA ver. 1.7.0; (4) Database used to calculate is Ecoinvent database; (5) Life Cycle Impact Assessment will use CML Baseline 2008; (6) Environmental impacts analysed are Global Warming Potential, Ozone Layer Depletion, Acidification, and Eutrophication (7) The functional unit in this LCA study is 1 kg sales gas.

We used CML midpoint impact assessment method for analysing the impact assessment since this method is globally provided for both software. The original database is suited for input data and both software programs' databases are matched to reduce the uncertainty analysis. SimaPro has a large original database, therefore this database is matched with the OpenLCA database. The life cycle impact assessment is analysed.

3. Results and Discussion

3.1 Impact Assessment Appearance

General LCA results provide four LCIA consecutive steps such as classification, characterization, normalization and weighting. On this research we only classify the impacts for global warming (in kg CO_2 eq.), ozone layer depletion (kg CFC-11 eq.), acidification (kg SO_2 eq.) and eutrophication (kg

PO_4 eq.) and analyze the characterization and normalization data since these data are provided specifically for substance concentration.

OpenLCA presented the impact assessment results with specific numerical values based on the method used (Figure 2) while SimaPro provided not only numerical values but also additional results with a coloured graph (Figure 1) that shows the production process and impact value. The coloured impact graph in SimaPro has percentage unit while raw data present specific impact concentration which may mislead the reader to make the wrong conclusion about the results. The percentage in SimaPro graph is calculated by total impact compared with same impact category in each process.

Both software programs did not only provide impact assessment results but also showed the contributors of the impacts and what processes generate the results. Figure 2 shows the impact contributors on OpenLCA that are directly shown on the impact result.

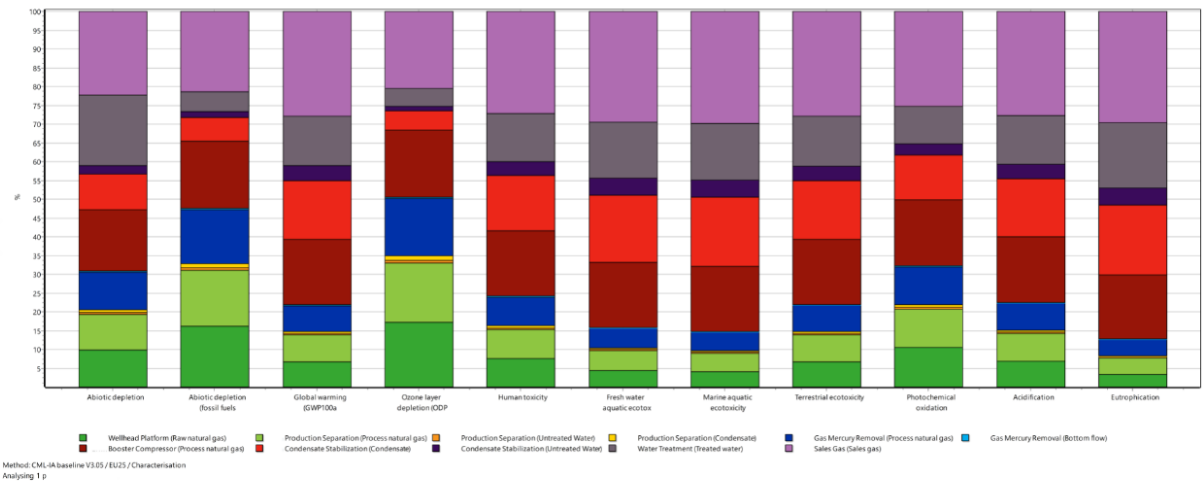
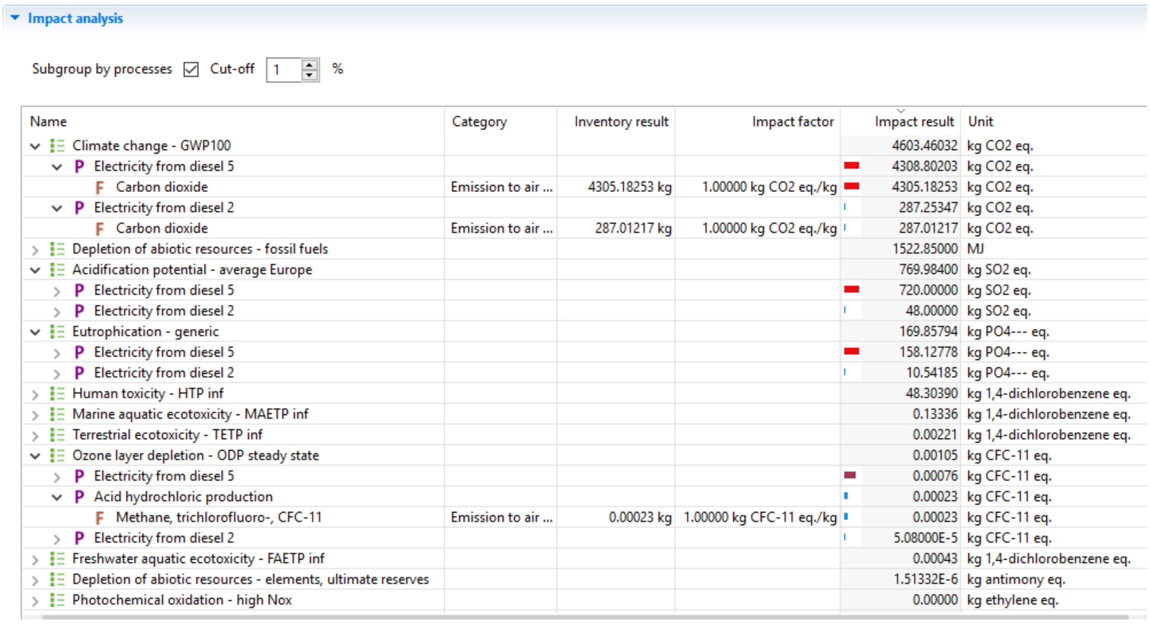


Figure 1. SimaPro coloured impact percentage graph



Name	Category	Inventory result	Impact factor	Impact result	Unit
Climate change - GWP100				4603.46032	kg CO2 eq.
P Electricity from diesel 5				4308.80203	kg CO2 eq.
F Carbon dioxide	Emission to air ...	4305.18253 kg	1.00000 kg CO2 eq./kg	4305.18253	kg CO2 eq.
P Electricity from diesel 2				287.25347	kg CO2 eq.
F Carbon dioxide	Emission to air ...	287.01217 kg	1.00000 kg CO2 eq./kg	287.01217	kg CO2 eq.
Depletion of abiotic resources - fossil fuels				1522.85000	MJ
Acidification potential - average Europe				769.98400	kg SO2 eq.
P Electricity from diesel 5				720.00000	kg SO2 eq.
P Electricity from diesel 2				48.00000	kg SO2 eq.
Eutrophication - generic				169.85794	kg PO4--- eq.
P Electricity from diesel 5				158.12778	kg PO4--- eq.
P Electricity from diesel 2				10.54185	kg PO4--- eq.
Human toxicity - HTP inf				48.30390	kg 1,4-dichlorobenzene eq.
Marine aquatic ecotoxicity - MAETP inf				0.13336	kg 1,4-dichlorobenzene eq.
Terrestrial ecotoxicity - TETP inf				0.00221	kg 1,4-dichlorobenzene eq.
Ozone layer depletion - ODP steady state				0.00105	kg CFC-11 eq.
P Electricity from diesel 5				0.00076	kg CFC-11 eq.
P Acid hydrochloric production				0.00023	kg CFC-11 eq.
F Methane, trichlorofluoro-, CFC-11	Emission to air ...	0.00023 kg	1.00000 kg CFC-11 eq./kg	0.00023	kg CFC-11 eq.
P Electricity from diesel 2				5.08000E-5	kg CFC-11 eq.
Freshwater aquatic ecotoxicity - FAETP inf				0.00043	kg 1,4-dichlorobenzene eq.
Depletion of abiotic resources - elements, ultimate reserves				1.51332E-6	kg antimony eq.
Photochemical oxidation - high Nox				0.00000	kg ethylene eq.

Figure 2. OpenLCA results based on total impact results

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3.2 Characterization and Normalization Comparison

Table 1 compares the characterization results between SimaPro and OpenLCA. The results indicated that impact values of global warming potential, ozone layer depletion, acidification, and eutrophication widely differ in number. For example, the global warming potential result in SimaPro was more than 200 million kg CO_2eq while OpenLCA only yielded around 700 hundred kg CO_2eq.

The impact assessment results were different between OpenLCA and SimaPro even when we used the same variable input, database and method. There are many probabilities that might have caused the wide deviation. We recognized that the database versions used were different between OpenLCA and SimaPro. In addition, though the method analysis was the same, there is a possibility that conversion and characterization factors were different in which we could not determine yet since the software programs' calculation were run in a closed system (blackbox).

Similar to this result, the observations presented in previous studies also indicated differences both at the inventory level and impact assessment. Some of these differences, in particular for impact assessment, are so large that they could potentially influence the conclusions drawn from an LCA study [4].

Table 1. Total impact characterization in SimaPro and OpenLCA

Impact category	Simapro	OpenLCA	Unit
Global warming (GWP100a)	277112233,00	769,98	kg CO_2 eq
Ozone layer depletion (ODP)	1423,57	4603,46	kg CFC-11 eq
Acidification	237403184,52	169,86	kg SO_2 eq
Eutrophication	115639189,30	0,00	kg PO_4 eq

We tried to normalize the result using normalization factor in each software. However, the deviation of these results remained wide (Table 2). On the characterization result, ozone layer depletion (ODP) in SimaPro had a lower result than OpenLCA while others had higher results. A different trend was shown in normalization results where a whole impact assessment result in SimaPro was higher than OpenLCA, including ozone layer depletion.

Table 2. Total impact normalization in SimaPro and OpenLCA

Impact category	SimaPro	OpenLCA
Global warming	0,0206392680	0,0000000009
Ozone layer depletion	0,0002102886	0,0000000000
Acidification	0,0016504780	0,0000000274
Eutrophication	0,0134377810	0,0000000129

The differences in the results generated by different software programs with the same input variables would influence the interpretation of the results. Therefore, it could affect the technical and economical approach taken by the companies or LCA practitioners. In example, the "Global Warming" impact value from SimaPro was almost 60% higher compare to that of OpenLCA. If a company wants to address the Global Warming impact with carbon footprint regulation and technical approach, the environmental cost will probably be 2-3 times higher if the decision is made based on SimaPro result. Other examples are related to the hotspot decision. SimaPro presents global warming as the highest impact, therefore the priority program must be addressed to the global warming contributor. However, for the same system production and data variable, OpenLCA addressed ozone layer depletion as the highest impact and the priority program must be directed for reducing ozone layer depletion. This condition will create a bias the and highest priority for environmental program may shift away from the original problem that lies within the company.

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3.3 Process Impact Contributor

Both SimaPro and OpenLCA have the capability to determine the impact contributor from each process. However, the impact contributor resulted from both software is different. As shown in Figure 3, the impact contributors generated from SimaPro and OpenLCA were dissimilar. For example, the highest global warming impact as analyzed by SimaPro was generated from gas mercury removal while OpenLCA presented it as electricity from diesel 5. In addition, the contribution percentage of global warming in the whole process was different. OpenLCA analyzed that more than 90% global warming was generated from electricity diesel 5 and the rest from diesel 2. On the contrary, SimaPro determined that 30% global warming was contributed from gas mercury removal followed by wellhead production (25%), condensate stabilization (20%). The lower contributors were sales gas compression, booster compression and production separation.

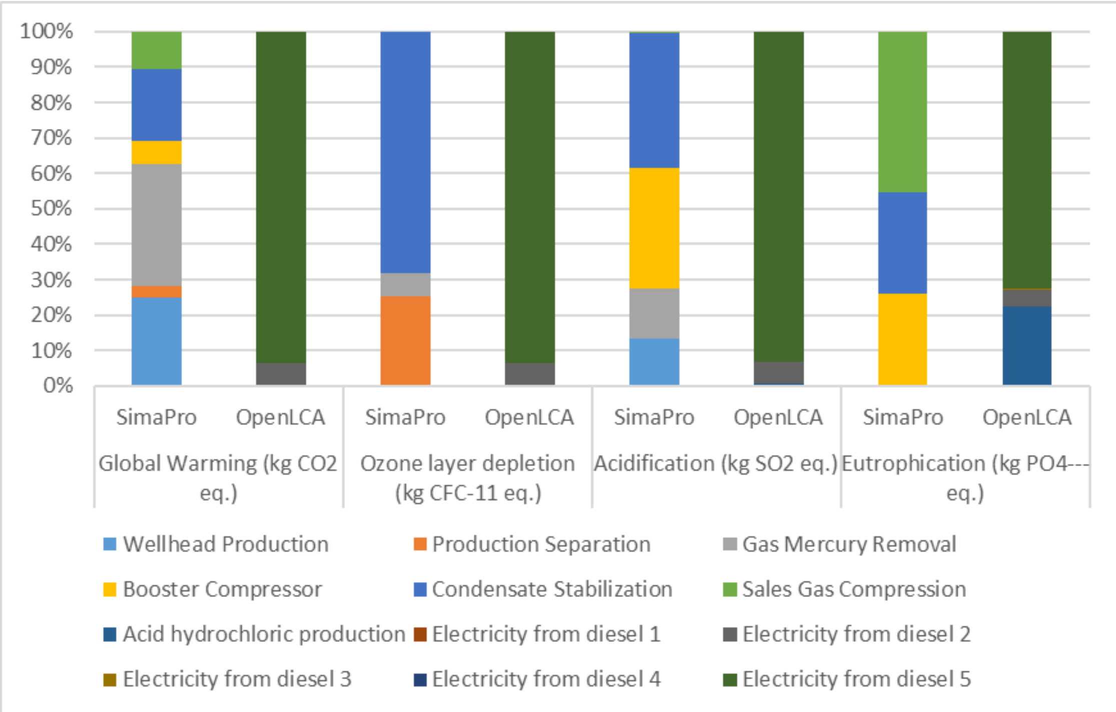

Figure 3. Characterization percentage of impact SimaPro and OpenLCA for each production process

Figure 4 shows the percentage contributor of environmental impact normalization in the entire process in the SimaPro and OpenLCA. Global warming was spotted as the largest normalization impact in SimaPro followed by eutrophication while OpenLCA presented acidification as the largest normalization impact followed by eutrophication.

During the research, we eliminated several factors that would probably be the cause of different results. We did not consider that database versions in SimaPro and OpenLCA could be different. We assumes the ecoinvent database used in this research was the same since we also modified the database in the OpenLCA and put the same variables, database and factors from SimaPro to OpenLCA. However, we overlooked the SimaPro database that could not be inputted to OpenLCA.

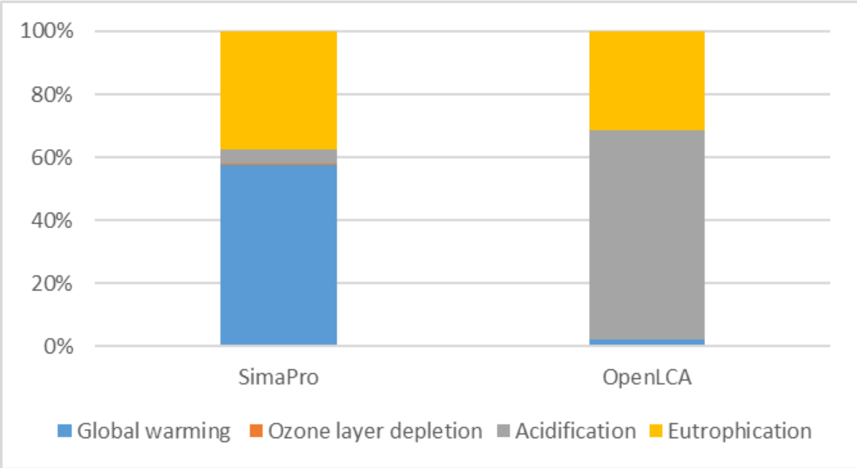

Figure 4. Normalization percentage of impact SimaPro and OpenLCA

4. Conclusions

Database and factors are important variables in this study since the principal of LCA is to analyze the input and output variables in each process with factors to generate the impact. Therefore, lack of conversion factors will cause different results.

Based on this study results, the results of software programs for life cycle assessment need to be validated further. The individual database from a software program needs to be assessed for generating local databases more suitable for assessing life cycle in Indonesian industries. Using software for LCA is easier and faster than manual calculation. However, the results need to be discussed more with experts and the interpretation is not only limited by data presented in the result analysis. Other variables which cannot be inputted in the software may contribute to changes in the hotspot decision or result interpretation.

Further studies need to be conducted on conversion factor of both software programs and how the database and factors are determined in the software. Thus, we may dig deeper on the unknown cause that generate different results.

It is highly recommended that when using software for LCA, we use only one software program for continuous assessment since the conversion factor remains unknown and may be different in each software. Also, results should be interpreted based on actual conditions in addition to LCIA result. The Indonesian government may set a standard for conversion factors and quality standards if they would like to use LCA as baseline study for environmental improvement program since the LCA results of different software programs are remarkably different. As we know, the current database and conversion factors available in Indonesia are of foreign standards which may lead to different results and be shifted from the original environmental problem.

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