Potential Benefit of Industrial Symbiosis using Life Cycle Assessment

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Abstract. Industry symbiosis is an environmental management approach that is part of industrial ecology. Industrial symbiosis requires a measurement tool that can measure intangible flows or non-physical flow. Creating industrial symbiosis at industrial estate can be done by uncovering industrial symbiosis, which is seeing the opportunity of material, energy, by product or water change. The potential flow of material and energy could build by seeing the opportunity of changing based on the raw material used and waste or by product produced. The objective of this paper is to saw the potential creating industrial symbiosis using LCA. Literature review and observation method used for data collection and Hyundai industrial estate choose as a population. Descriptively method used for data analysis method. The result showed the potential industrial symbiosis could proceed to see the opportunity by saw the result of LCA. LCA is a measurement tool that can be used in measuring all material and/or energy that used in industry. From LCA gate-to-gate analysis founded that waste and by product produced which were the emission, scrap and CO₂ emission could show clearly. Thus, LCA is a very useful tool in uncovering industrial symbiosis and could measure the environmental impact of applying industrial symbiosis.

Keywords: industrial symbiosis, life cycle assessment, uncovering, material flow, energy flow

1. Introduction

Environmental management in an industrial environment, which is an artificial ecosystem, can use industrial symbiosis. Industrial symbiosis is one approach of industrial ecology that is mostly done in an industrial area. In the implementation of industrial symbiosis, the consideration is the exchange of materials, energy, by-products and water [1]. The exchange of these four things happened between different companies. The application of industrial symbiosis allows to reuse material, energy, by-product and water in production activities at different company. Material exchange component could refer to a by-product exchange, by-product synergy, or waste exchange and could be referred to an industrial recycling network [2].

The industrial symbiosis that took place in Kalundborg is often used as an example of an excellent symbiosis among companies. It happens with one company that dominates, then comes another company that utilizes the remaining material, energy, water or by-product. There are three main possibilities in resource exchange [3], namely reuse by-product, joint use of infrastructure facilities and joint provision of services. Reuse by-product by other companies, often as a raw material (input), resulting in dependence on raw materials, and also production process itself.

The development of the definition of industrial symbiosis shows that in the implementation of industrial symbiosis there is not only physical exchange (material, energy, by-product and water) but also the occurrence of knowledge exchange and expanding the network also provides added value and
enhances the usefulness of resources [4]. Industrial symbiosis does not only look at physical exchanges but also occurs with the exchange of knowledge, information that is not physical objects.

Industrial symbiosis at Kalundborg is an evolution process that takes about 30 years. If you are going to build a symbiosis industry by following the experience in Kalundborg, of course there is not enough time, because the environmental impact is already at an alarming level. Therefore, the formation of industrial symbiosis in existing industrial areas by looking at the potential for the exchange of material, energy, by-products or water. The formation of symbiosis in the brain like this is commonly referred to as uncovering industrial symbiosis.

This paper aims to see the potential benefits obtained in using LCA as a tool to see the use of resources (material or energy) in an industrial area's activities, so that the formation of industrial symbiosis through uncovering industrial symbiosis becomes easier and faster.

2. Method
This paper using literature and observation were carried out in order to achieve the main goal of this paper. For build the potential industrial estate, companies at Hyundai Industrial Estate used as a samples from all companies that located at industrial estate in Cikarang District. Literature review for finding the potential material flow among the companies at Hyundai Industrial Estate. From web of Hyundai industrial estate, the number of companies in this industrial estate are 10 companies. Based on the product that produced by companies, the materials used and the waste and by product got from production process, potential industrial symbiosis had been constructed. This potential industrial symbiosis still as a proposed with very early condition. To build the industrial symbiosis itself need to have more research and investigation.

Goal and scope using LCA had been in production process of clutch cover model 380A-8.5. This scope as a gate to gate which the shortest life cycle and just analyzes the closest activity. Collection data method to describe the production process using observation method. Production process of clutch model 380A-8.5 consist of stamping cover, stamping diaphragm spring, stamping strap clutch and assembly activities. For inventory input and output in clutch production process considered in using the electricity and CO2 emission and scrap.

Data analysis was performed descriptively with the support of literature and comparing the use of materials and energy and waste generated by companies that have not used LCA with those who have used LCA. The results of the study in the form of research papers were used to build logic to see the potential benefits of applying industrial symbiosis by using LCA tools.

3. Results and Discussion

3.1. Industrial Symbiosis
The application of industrial symbiosis requires collaboration and synergy between different industries. The definition of industrial symbiosis is conveyed by [3], “as engaging traditionally separate industries in a collective approach to competitive advantage involving physical exchange of material, energy, water, and by product”. From this definition, it can be said that physical exchange occurs among industries were considered in industrial symbiosis. These material, energy, water, and by-product flow can form a balance and if expanded the application of industrial symbiosis will form a cycle. The flow among industries in industrial symbiosis as a physical flow.

As it is known that industrial ecology can operate at three levels of implementation, namely at the facility level, inter-company level and regional / global level [5]. At the facility level, material flow, energy, water and by-product have not formed a cycle because not all roles / organisms in the artificial ecosystem are available. The phenomenon of ecosystems in the industrial environment can form food chains, namely in the form of reuse of waste in an industry to be an input for other industries and various residual materials that are reused can be analogous to decomposers.

Material exchange on industrial symbiosis is a consideration for classifying spatial scale into 5 types, namely: type of waste exchange, type of within facility, firm or organization, type eco industrial park,
among companies in the same location, type among companies that are not in the same location and type among companies that are organized virtually, this can go beyond the boundary [5]. From this classification, the border of industrial symbiosis implementation not at certain physically location or have geographic proximity.

Geographic proximity is neither necessary nor sufficient for industrial symbiosis [4]. According to [3], geographic proximity usually offers collaboration and synergy as a key for industrial symbiosis. Location of company linked as an organism’s habitat in natural ecosystem. The linked among organism happened in ecosystem as an interdependences relationship. In industrial symbiosis spatial relationship has been translated in two ways: for impact of transport and for the close “mental distance” of the participant [4]. Transportation cost or delivered cost as a consideration for delivered waste, by-product, water or energy, among company, especially for industrial symbiosis as a waste exchange type. For mental distance derived from geographic proximity however in a supply chain prevalent and have opportunity to enable relationship and building trust among parties [4]. The model of industrial symbiosis at Kalundborg, showed in Figure 1.

![Industrial Symbiosis at Kalundborg](image)

**Figure 1.** Industrial symbiosis at Kalundborg. [6]

Industrial symbiosis in Figure 1, shows the flow of water that used by companies. Calculating water balance would show water that taken from ecosystem until return to nature. [5] has delivered several tools that can be used to see the implementation of industry symbiosis. The first tool is input-output matching. This calculation tool explains the input types and output specifications that are in a business service. The second tool is process stakeholders. The use of this tool will be very complex because you want to see the relationship between many parties. The last tool is materials budgeting, which uses materials used to map materials and energy.

Calculation tool used in the application of this industrial symbiosis to show the life cycle perspective. Life cycle perspective ensures a breadth of focus that is not limited to what happens within a facility or rather than considers the entire set of environmental impacts that occur at each stage of the product life cycle and use across entities [1]. The tool used is able to show the symbiosis process that occurs so that the life cycle of material, energy, water, and by-product is formed.
Revised the definition of industrial symbiosis to “a diverse organization in a network to foster eco innovation and long-term engagements in culture change. Industry symbiosis can occur among non-industrial organizations, given the flow of energy can occur between these organizations”. Creating and sharing knowledge through the network yields, mutually beneficial, non-product outputs, and improved business and technical processes. Redefining industrial symbiosis by [4] shows that there is a non-physical flow that occurs in industrial symbiosis. Therefore, the tools used to assess industry symbiosis must be able to measure the non-product flow.

The 10 companies as sample could showed the product and type of industry (Table 1). Based on Table 1, proceed to find the production process at each company and potential waste that could occurred. Finding the production process using the literature and other information, such as report or previous research. The list of all production activities and potential waste or by product and also energy using showed at Appendix 1.

| Number | Company                          | Product          |
|--------|----------------------------------|------------------|
| 1      | PT Vinotindo Graha Sarana        | Baby diapers     |
| 2      | PT Elleair International          | Wood furniture   |
| 3      | PT Cahya Prima Sentosa           | Printing         |
| 4      | PT Putra Pile Indah              | Textile          |
| 5      | PT Hung A Indonesia              | Tyres            |
| 6      | PT Sinar Syno Indonesia          | Ink              |
| 7      | PT Rappipack Asritama            | Packing box      |
| 8      | PT Enkei Indonesia               | Aluminium casting|
| 9      | PT Astaguna Wisesa               | Jam              |
| 10     | PT Daewa Leather Lestari         | Leather          |

Creating potential industrial symbiosis at Hyundai industrial estate shown by seeing the product that produced by companies and the waste or by-product that occurred. After make a list of waste generated and potential pollution made by production process from all companies (Appendix 1). From 10 companies at Hyundai industrial estate, the potential material flow shown at Fig.2.

Potential material flow at Figure 2, just the potential flow that could happen among the companies [7]. To proceed in becoming industrial symbiosis, the research needs to be deep and comprehensive. The perspective of the life cycle will be very visible in the use of LCA, because LCA will show the use of input that is considered starting from the moment it enters the environment until it returns to the environment. In addition, the development of industrial symbiosis that leads to non-physical flow, such as information flow, knowledge sharing, making the tools used must also accommodate it.
3.2. Life Cycle Assessment (LCA)

The use of LCA in assessing material flow, energy, water and by-product means measuring the use of these materials starting from the beginning of entering the environment until the environment returns. This shows a thorough calculation, so that it can see the life cycle process of matter and energy as it happens in nature. Material exchange between organisms in natural ecosystems can be fully calculated.

For measurement of physical flow from material, energy, water, and by-product, other measurements can also be used, because it is a measurement of physical flow. However, for non-physical flow measurement, the use of LCA is very important because LCA allows to measure the flow of services. According to [8], in service industries the value creation and intangible way at the same time promotes dematerialization, that is need for adequate assessment of environmental aspects and potential impacts of services, and the impact to environment indirectly but contributing to environmental burdens. Thus, the use of LCA in industrial symbiosis that develops to non-product flow is possible, because LCA can measure intangible flow.

According to [9], the added value is not centered on the transfer of material or finished products, but on providing a function desired by the customer—a “dematerialized” added value, at least from the customer’s standpoint. In this paper, using LCA to see the environmental impact, by measure the impact with qualitative scale.

Scoping for life cycle assessment in covering process of clutch in making a clutch model 380A-8.5 [10]. Manufacturing process scoping from stamping to assembly of clutch. The production process as a gate-to-gate analysis showed at Figure 3.
Figure 3. Production process of Clutch cover model 380A-8.5 (gate to gate).

From Figure 3, the process consists of stamping, head treatment, manufacturing, sub assy and assembly (showed with the box). From this gate-to-gate process, proceed with the input and output material and energy analysis or inventory analysis along the process. The input output analysis showed in Figure 4. To get the calculation of CO₂ emission, just limit in using electricity only, with factor from Toyota standard which 0.7393 kg-CO₂/kwh.

Figure 4. Input and output of Clutch cover model 380A-8.5 production.

The result from LCA analysis showed in six impact categories, which were GWP 100A/climate change, photochemical oxidation, human toxicity, terrestrial toxicity, acidification and eutrophication. The result of LCA analysis showed in Table 2. For this process, the largest CO₂ emission was from heat treatment diaphragm spring which was 1.5582 kg CO₂ eq/kg. This process gave the highest contribution for all impact compare with the other process.

From inventory activities (Figure 4) could find that from certain process would produce scrap as a material waste, or emission as a head of by product or CO₂ emission. These waste and emission if produced continuously could use for certain activities that need to have head or this scrap. If the LCA analysis could running from cradle to grave or wider scope, it’s mean the potential waste or by product would increase in quantity and in function.
Table 2. Impact result from LCA.

|                | STP Cover | STP DS | STP Strap | HTDS | MADS | SA Strap | SACC | ASCC |
|----------------|-----------|--------|-----------|------|------|----------|------|------|
| GWP 100A kg CO2 eq/kg | 1.3125 | 0.15953 | 0.0038 | 1.5582 | 1.1523 | 0 | 0.2111 | 0.6277 |
| Photochemical Oxidation kg C2H4 eq/kg | 0 | 0 | 0 | 0.000013627 | 0.000013626 | 0 | 0 | 0 |
| Human Toxicity kg 1.4-db eq/kg | 0 | 0 | 0 | 1.4709 | 1.4664 | 0 | 0 | 0 |
| Terrestrial Toxicity Species yr/kg | 0 | 0 | 0 | 0.006744 | 0.006723 | 0 | 0 | 0 |
| Acidification kg 1.4-db eq/kg | 0 | 0 | 0 | 0.0003199 | 0.0003198 | 0 | 0 | 0 |
| Eutrophication kg PO4 eq/kg | 0 | 0 | 0 | 0.0000136 | 1.36E-05 | 0 | 0 | 0 |

4. Conclusion
The application of industrial symbiosis will be increasingly developed and not only limited to physical exchanges or flows such as material flow, energy, water, and by-product. The development of industrial symbiosis that also looks at the flow of information and knowledge, requires a measuring device that is able to measure the non-physical environmental impact cycle. LCA is an environmental impact measurement tool that can be used for physical cycles and non-physical cycles. Thus, the use of LCA has a very beneficial potential to measure the application of industrial symbiosis.

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