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Dynamic System of Industrial Symbiosis in the Energy Sector to Support Industrial Estate Sustainability in Indonesia*

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The industrial sector is a major sector in the Indonesian economy that plays an important role in the national development. The industrial sector is expected to become a motor of the national economy and has put the manufacturing industry as a driving force for real sector. Energy has a very important role in sustainable national development, especially to support the industrialization process that serves as fuel and raw materials. The utilizing of energy in Indonesia increased rapidly in line with economic and population growth. Indonesia, as the tropical agricultural country, has several potential sources of renewable energy, which are biomass energy. The concept of industrial symbiosis is particularly relevant to the utilization of biomass waste for energy purposes as the concept is designed to facilitate the optimization of by-product and waste between industries. Industrial symbiosis is important for sustainability, not only because how wastes are handled, but also because it addresses the social and economic aspects of sustainability. The purposes of this study are: (1) planning the industrial symbiosis model in the energy sector to increase the industrial estate (IE) sustainability performance; and (2) creating the scenarios of industrial symbiosis in the energy sector through the utilization of by-products and waste generated by industry in the region and the utilization of biomass from agricultural waste and manufacturing industries waste.

Keywords: industrial symbiosis, energy, biomass, sustainability performance, industrial estate (IE)

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development. The industrial sector is expected to become a motor of the national economy and has put the manufacturing industry as a driving force for real sector. This is understandable given the variety of rich natural resources that have a comparative advantage in the form of primary products and need to be processed into industrial products to obtain a higher added value. Manufacturing industry is the largest contributor in Indonesia's gross domestic product in 2009 that is equal to 26.4% (BPS, 2010).

Industry, in general, in the globalization and free trade era and the current turbulent situation, will enter into the very tight competition. Djajadiningrat and Famiola (2004) argued that the industrial sector was the most highlighted sector in environmental change over the years, then the challenge faced by industry was not limited to the high competition in the economic context, but the market would also be influenced by environmental issues, because there would be no effort that would change the pattern of industrial production over the years without the influence of the market. Therefore in the market, environmental issues will emerge as one of the prerequisites to be accepted by consumers.

Companies that compete globally are increasingly required to commit to and report on the overall sustainability performances of operational initiatives. Sustainability performance of industry is needed to ensure that progress achieved by human is sustainable without wasting natural resources for future generations. According to Deloitte and Touche, business sustainability is adopting business strategies and activities that meet the needs of the enterprise and its stakeholders today while protecting, sustaining and enhancing the human and natural resources that will be needed in the future (Labuschagne, Brent, & Van Erck, 2005; Brundtland, 1987).

Energy has a very important role in sustainable national development, especially to support the industrialization process that serves as fuel and raw materials. The use of energy in Indonesia increased rapidly in line with economic and population growth. Indonesia as the tropical agricultural country has several potential sources of renewable energy which are biomass energy. An estimated amount of waste from manufacturing industry of agricultural and forestry reached 12 million tons per year. With the availability of the waste, actually the potential value of biomass that could be developed in Indonesia reached 49.81 Giga Watt (GW). Meanwhile, the value has developed until now still reached 0.3 GW[1].

The concept of industrial symbiosis is particularly relevant to the utilization of biomass waste for energy purposes as the concept is designed to facilitate the optimization of by-product and waste between industries. What makes industrial symbiosis relevant to utilization of biomass waste is related to the fact that biomass is an abundant resource. The utilizing biomass waste and by-products from agriculture forestry and the manufacturing industries are a way by which the energy demand can be fulfilled with a low net increase in CO_2 emissions without compromising the need for food (Christensen, 2009).

The purposes of this study are: (1) planning the industrial symbiosis model in the energy sector to increase the industrial estate (IE) sustainability performance; and (2) creating the scenarios of industrial symbiosis in the energy sector through the utilization of by-products and waste generated by industry in the region and the utilization of biomass from agricultural waste and manufacturing industries waste.

Industrial Symbiosis

Chertow (2000) defined the industrial symbiosis as engaging traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products. The

[1] See *Biomass alternative energy from food industrial waste*. Retrieved July 14, 2011, from http://www.alpensteel.com/article/60-108-energy.

keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity. Industrial symbiosis is principally concerned with the cooperative management of resource flows through networks of businesses as a means of approaching ecologically sustainable industrial activity (Chertow, Ashton, & Kuppali, 2004; Chertow, 2007).

Fujita, Wong, and Kurihara (2004) have reported the results of their research in the IE of Kawasaki Eco-town, namely: (1) The general information of Kawasaki Eco-town was described as well as industrial symbiosis activities in the world; (2) The research framework was designed consisting of integrated evaluation system, eco-reporting system, and the assessment of spatial material flow; and (3) The tentative research findings from the industry interview were provided such as material conversion system of factories, and the policy patterns were identified. Zhu, Lowe, Wei, and Barnes (2007) also reported that industrial symbiosis strategy implemented in the Guitang group company has generated new revenues and reduced environmental emissions and disposal costs, while simultaneously improving the quality of sugar. Bansal and McKnight (2009) suggested that the industrial symbiosis was important for sustainability, not only because how wastes were handled, but also because it addressed the social and economic aspects of sustainability.

Gertler (as cited in Mirata, 2005) argued that through the establishment of symbiotic connections the following effects could be realized:

(1) Use of virgin materials as resource inputs can be reduced;

(2) Pollution can be reduced;

(3) Systemic energy efficiency can be increased leading to decreased systemic energy use;

(4) The volume of waste products requiring disposal can be reduced, with the added benefit of preventing disposal-related problems;

(5) The amount and types of process outputs that have market value can be increased.

The best-known example of industrial symbiosis in action is the small city of Kalundborg in Denmark. Here, the primary business partners include an oil refinery, a power station, a gypsum board facility, and a pharmaceutical company that literally share ground water, surface water, wastewater, steam, and fuel, and exchange a variety of by-products that become inputs in other processes (see Figure 1). Industrial symbiosis in Kalundborg has resulted in substantial economic and environmental benefits. Approximately three million cubic meters of water, 20,000 tons of oil, 80,000 tons of coal ash, and 200,000 tons of virgin gypsum are saved annually through the industrial symbiosis exchanges (Chertow, Ashton, & Espinosa, 2008).

Christensen (2009) has reported his research results that the symbiosis concepts revolved around three selected conversion technologies: biogas, CHP (combined heat and power) generation on the basis of incineration, and IBUS 2 (Integrated Biomass Utilization System) generation bio-ethanol fermentation technology. The result of the analysis was the identification of four generic concepts for industrial symbiosis in the energy sector:

(1) Concept 1: small scale biogas based on a broad range of resource;

(2) Concept 2: medium-sized biogas facility linked to the multifunctional agriculture;

(3) Concept 3: medium-sized biogas facility linked to established industries and energy crops;

(4) Concept 4: IBUS 2 generation bio-ethanol fermentation linked to CHP plants.

The industrial symbiosis framework recognizes the public benefits that ensue such as fewer emissions from energy systems, increasing use of cleaner or renewable energy sources, and reducing demand and impact on water systems (Chertow et al., 2008).

By-Product and Waste Exchange to Energy

By-products and waste materials are potentially valuable inputs into a variety of industrial processes and can be exchanged to energy. Industrial waste exchange is an internationally recognized waste reduction concept. It is a mechanism for recycling and reusing industrial waste. This form of waste exchange attempts to link industrial waste generators with waste recyclers or companies that can use waste as a raw material input to their products.

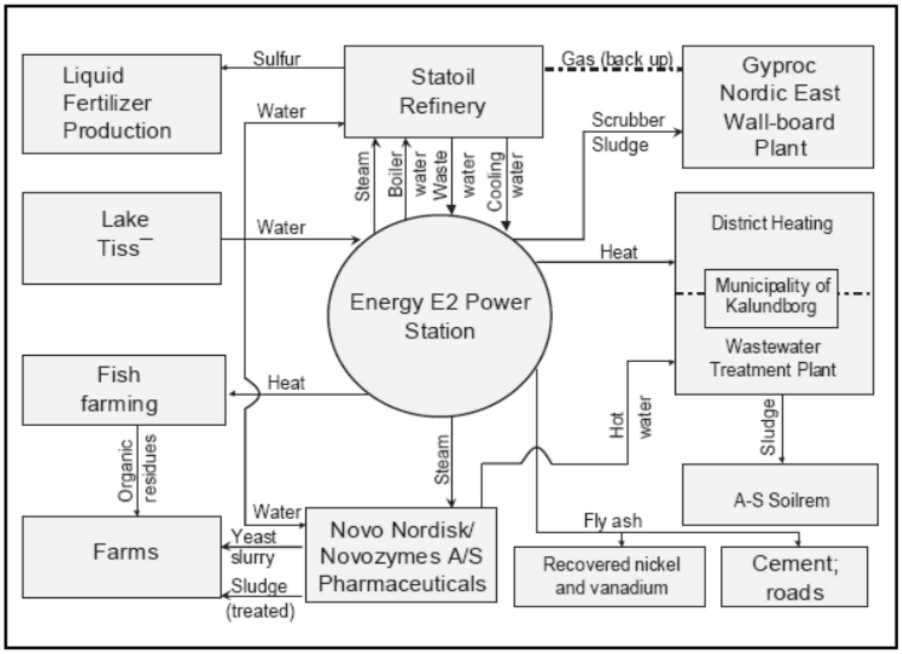

Figure 1. Industrial symbiosis in Kalundborg, Denmark. Source: Chertow et al. (2008).

Waste-to-energy (WtE) or energy-from-waste (EfW) in its strictest sense refers to any waste treatment that creates energy in the form of electricity or heat from a waste source that would have been disposed in landfill. More advanced WtE processes result in usable fuel commodity, such as hydrogen or ethanol. The term of WtE means the use of modern combustion technologies to recover energy, usually in the form of electricity and steam, from mixed municipal solid wastes. These new technologies can reduce the volume of the original waste by 90%, depending upon composition and use of outputs. In OECD (Organization for Economic Co-operation and Development) countries, all new WtE plants must meet strict emission standards. Modern WtE is considered to be a source of partly renewable energy by the U.S. federal government and 15 U.S. states that have established renewable energy programs. Also some European countries that have established renewable energy programs consider energy production through WtE as renewable. To determine the percentage of WtE output that qualifies as renewable, there must be a measurement of the percentage of the feedstock coming from biological sources (e.g., food, paper, fabric, wood, and leather) and from fossil fuel sources, namely plastics (Wagner, 2007).

Wagner (2007) concluded from his research that the recycling of materials had environmental and energy advantages over combustion with extraction of energy, on the condition that the recycled materials were really used to replace new raw materials, such as raw materials from forestry or crude oil. The recycling of plastics yields substantial advantages over combustion, for example in terms of reduced energy usage and reduced emissions. Recycling of metals contributes to reduced energy consumption and environmental impact. For instance, it is 95% less energy-intensive to produce aluminum from recycled aluminum products than from aluminum ore.

Biomass materials are used since millennia for meeting myriad human needs including energy. Main sources of biomass energy are trees, crops and animal waste. Until the mid-19th century, biomass dominated the global energy supply with a seventy percent share. Among the biomass energy sources, wood fuels are the most prominent. With rapid increase in fossil fuel use, the share of biomass in total energy declined steadily through substitution by coal in the 19th century and later by refined oil and gas during the 12th century (Shukla, 1997).

Energy and Waste Management in Indonesia

Indonesia has large new and clean energy potential, which includes 50 GW of biomass (Ministry of Energy and Mineral Resources, 2008). With regard to energy from waste, currently the government has generated two megawatt (MW) of energy, which is targeted at 26 MW by 2013. Organic municipal waste is identified as one of the potential sources of biomass energy. The types of wastes produced in Indonesia mainly consist of organic matter (65%). The major sources for MSW (Municipal Solid Waste) are residential localities. Considering these facts, the waste in the landfill is mostly comprised of household organic wastes that produce methane, therefore potential for energy generation (Aprilia, Tezuka, & Spaargaren, 2010).

The energy sector in Indonesia is dominated by key policies and objectives related to the following:

(1) Diversification: A key objective of the GOI (Government of Indonesia) is to reduce dependence on oil by expanding the use of coal, gas, and renewable energy sources. Specific targets are set for each energy source in 2025;

(2) Rational energy pricing: The GOI recognizes that it can no longer sustain uniform pricing for electricity and petroleum products across the country, and has begun to scale back fuel subsidies;

(3) Energy conservation: As an impact of increased crude oil price since 2005, the GOI is increasingly promoting energy efficiency measures in both the public and private sectors;

(4) Energy sector reform: The combination of decentralization of government decision-making and the need to attract capital for investment in the energy sector makes energy sector reform—including greater transparency in planning and decision-making—a critical priority for the government;

(5) Rural electrification: The GOI wants to bring electricity to 90% of the population by 2020.

According to Indonesia Energy Report[2], in 2010 oil was the country's dominant source of energy, providing 30% of the total. Biomass came second with 25%, while coal accounted for 23%, gas for 18% and primary electricity (hydroelectricity, geothermal) for 4% (2010). The weight of coal is increasing strongly compared to oil. The structure of the country's final energy consumption is as follows: biomass (34%), oil (33%), gas (9%), electricity (8%) and coal (16%) (2010). In the residential-tertiary sector, non-conventional energies (wood, residue) play an important role (around 70%). Oil covers just 18% of consumption and is used for cooking and lighting in non-electrified households. Shares of sector in final consumption are as follows: 34% for industry (21% in 1990), 17% for transport (13% in 1990), and 42% for the residential-tertiary sector (55% in 1990), with the rest corresponding to non-energy uses of energy (7%).

[2] Retrieved from http://www.enerdata.net.

Municipal Waste Management (MWM) contributes to the overall health and environment conditions of urban cities. And 60% of the garbage in Indonesia ends up in final disposal sites where the wastes are stacked in an open dump. Within Indonesian cities, the average waste management collection coverage is partial, estimated to be between 40% and 50%. The uncollected waste is disposed off (or burned off) in an unregulated manner that results in environmental problems. Insufficient management of the landfills in Indonesia has led to environmental problems, including the infiltration of leachate (the liquid produced in a landfill from the decomposition of waste within the landfill) into the water supply. It is estimated that Indonesia produces 10 million tones of municipal waste annually. The organic component of the waste could potentially yield 400 million m^3 of methane. The reduction of methane gas through sustainable management of municipal waste could possibly provide 80 MW of continuous power generation and US$10 million annually in carbon credit revenue (REEEP, 2009).

Industrial Symbiosis in the Energy Sector in JBK IE

The research is being conducted in the JBK IE of West Java province, as a case of study. According to Annual Report 2010, JBK IE had a total development area of 5,600 ha, of which 1,570 ha for industries (the composition of industry type was presented in Figure 2), 1,400 ha for residential, 80 ha for educational park and 16 ha for commercial estate. JBK IE is home to more than 1,500 local and multinational companies from 30 countries that employ over 600,000 workers and 2,500 expatriates (JBK, 2010).

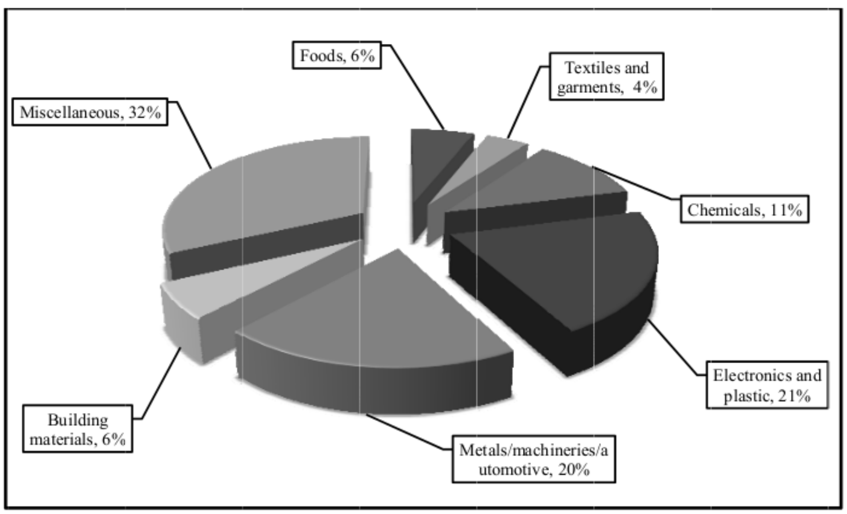

Figure 2. Type of industries in IE of JBK. Source: JBK (2010).

JBK IE in fulfilling the needs of electrical energy is obtained from the power industry I 500 MW, power industry II 130 MW, and power industry III 50 MW. In addition to electrical energy, the existing industries in JBK IE for their production process activities also use energy derived from fossil fuels (not renewable), for example, used in boilers equipment to producing steam, generators and others.

Industrial symbiosis modeling in the energy sector to increase the sustainability performance of JBK IE performed using the System Dynamics simulation model (Muhammadi, Aminullah, & Soesilo, 2001). This modeling developed three scenarios, namely the initial scenario (business as usual, BAU) and two alternative scenarios. The initial scenario is a continuation of the historical development without any policy intervention that can change the historical behavior. Scenario I is the scenario with the intervention of the policy of energy conservation and symbiosis from processing results of by-products and waste generated by industries in the IE. Scenario II is the scenario I plus the scenario of the establishment of biomass processing plant into energy sources to reduce dependence on fossil energy and reduce greenhouse gas emissions, as well as increase the IE sustainability performance.

Industrial Symbiosis Modeling in the Energy Sector

Causal Loop Diagrams (CLD) which shows the relationship between variables in the problem of increasing the sustainability performance of the JBK IE as a business as usual can be seen in Figure 3.

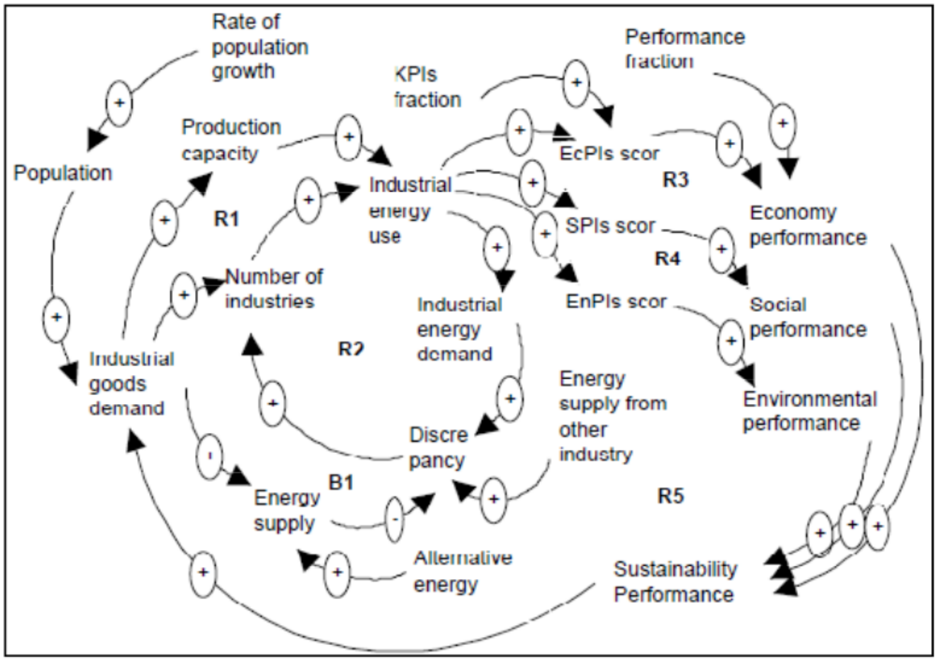

Figure 3. CLD of sustainability performance improvement model of IE (early scenario).

An increase in population led to increased demand of industrial goods and will spur an increase in the number of industry and production capacity. An increase in the number of industry and production capacity will be followed by an increase in industrial energy's needs. The high discrepancy between demand and supply of energy will increase the amount of industry producing energy, and can increase the emission of exhaust gases and solid particles. If no efforts to improve energy efficiency, conservation and utilization of industrial symbiosis to exchange by-products and wastes for energy, as well as the procurement of energy from renewable biomass materials, it will cause economic, social and environmental problems, so it can degrade the economic, social and environmental performance, as well as sustainability at the IE.

The research project on industrial symbiosis in the energy sector to improve sustainability performance in the JBK IE is still going on, so it has not yet obtained the final result. Based on the initial CLD that shows the relationship between variables in the problem of industrial symbiosis in the energy sector to increase JBK IE sustainability performance, furthermore the initial Stock Flow Diagrams (SFD) can be made. Similarly, from the CLD 1 (scenario I) SFD 1 can be made, and from the CLD 2 (scenario 2) SFD 2 can be made.

The increasing industrial activities that are triggered by an increase in industrial products' demand will increase energy's demand. Increased energy's needs will increase the utilizing of energy resources limited. So it needs to be done intervention through the scenarios that can reduce dependence fuel oil consumption, reduce the risk of environmental impact, by using the benchmark of energy conservation opportunities from the National Energy Conservation Master Plan for 15%-30% (Hindarto, 2011), this will greatly affect the energy efficiency improvement, while increasing economic performance, environmental performance, social performance, and sustainability performance of IE.

Conclusions

Industrial symbiosis is important for sustainability, not only because how wastes are handled, but also because it addresses the social and economic aspects of sustainability. The concept of industrial symbiosis is particularly relevant to the utilization of biomass waste for energy purposes as the concept is designed to facilitate the optimization of by-product and waste between industries. Based on the initial CLD that shows the relationship between variables in the problem of industrial symbiosis in the energy sector to increase JBK IE sustainability performance, furthermore the initial SFD can be made. Similarly, from the CLD 1 (scenario I) SFD 1 can be made, and from the CLD 2 (scenario 2) SFD 2 can be made, by using the system dynamics software, then the ahead predictions about expected conditions can be done. Through scenario of the utilization of by-product and waste generated by industries in the IE, the utilization of biomass from agricultural waste and manufacturing industries waste will greatly affect the improvement of energy efficiency that can simultaneously improve economic performance, environmental performance, and social performance, as well as sustainability performance of IE.

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